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THE MINERALOGICAL SOCIETY

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EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, June 20th, 1900.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

The deaths of the Duke of Argyll, Mr. Alex. Cruickshank, and Captain Dowler, Ordinary Members of the Society, were announced.

In regard to an application from the Royal Society relative to an International Scientific Catalogue, Mr. L. J. Spencer was nominated as a representative of Mineralogy and Crystallography for the Regional Bureau, and the Council undertook to supply the slips requisite for indexing the literature in those subjects published in Great Britain and Ireland.

GENERAL MEETING.

Held in the Apartments of the Geological Society, June 20th, 1900.

Mr. N. S. Maskelyne, M.A., F.R S., Past President, in the Chair.

Fourteen Members and One Visitor were present.

The following papers were read:—

1. On Conchite, a new variety of calcium carbonate: by Miss Agnes Kelly. (Communicated by Professor Miers.)

2. On the general determination of the three principal indices of refraction from observations made in any arbitrary zone: by Mr. G. F. Herbert Smith, B.A.

3. On Monazite from Tintagel: by Mr. H. L. Bowman, M.A.

4. On the oxidation of Pyrites by underground water: by Mr. J. W. Evans, D.Sc.

5. Petrological Notes: by Mr. G. T. Prior, M.A.

6. A quantitative determination of the action of hydrochloric acid and of soda-solution on the enstatite and felspar of the Mount Zomba meteorite: by Mr. L. Fletcher, M.A., F.R.S.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, October 9th, 1900.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

The Minutes of the last Council Meeting, held June 20th, 1900, were read and confirmed.

The resignation by Professor Miers of the Editorship of the Journal, held by him since 27th January, 1891, was announced, the resignation to take effect after the publication of the Number of the Journal now in the press. A vote of thanks to Mr. Miers for the services rendered by him in his editorial capacity was carried with acclamation. Mr. L. J. Spencer was appointed to succeed Professor Miers as Editor of the Journal.

Resolved to nominate Mr. J. H. Collins, Professor Lewis, Professor Miers and General McMahon to replace the four retiring Members of Council (Professor Cole, Dr. Gurney, Mr. Mallet and Mr. Prior).

The draft Bye-laws submitted to the Council on behalf of the Committee (Professor Church, Mr. Beale, Mr. Scott and Mr. Fletcher) appointed at the last Anniversary Meeting, were amended and approved: the General Secretary was instructed to send a copy to every Ordinary Member of the Society, and to give notice that the substitution of the Bye-laws for the present Rules would be proposed at the Anniversary Meeting.

EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Apartments of the Geological Society, November 13th, 1900.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

The Minutes of the last Council Meeting, held October 9th, 1900, were read and confirmed.

The deaths of Professor Waage, Corresponding Member, and Mr. Greenwell, Original Member, were announced.

Mr. F. N. A. Fleischmann was elected an Ordinary Member of the Society.

The following were selected as the dates of meeting for the year 1901: —January 22, April 2, June 18 and November 12, the latter to be the Anniversary Meeting.

The draft Annual Report of Council, submitted by the General Secretary, and the proposed Bye-laws of the Society, were amended and approved.

ANNIVERSARY MEETING.

Held in the Apartments of the Geological Society, November 13th, 1900.

Professor A. H. Church, M.A., F.R.S., President, in the Chair.

Eighteen Members were present.

The Minutes of the last General Meeting, held June 19th, 1900, were read and confirmed.

Messrs. Evans and Spencer, having been nominated by the President to act as scrutineers of the voting papers for the election of Officers and Council, reported that 40 voting papers had been returned, and that the List as nominated by the Council had been approved, namely :—

President.	Prof. A. H. Church, M.A., F.R.S.
Vice-Presidents.	Prof. G. D. Liveing, M.A., F.R.S. Mr. Hugo Müller, Ph.D., F.R.S.
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The following Report of Council was read by the General Secretary : —

REPORT.

The Balance Sheet for the year ending December 31st, 1899, which was issued with Number 57 of the Journal, showed that the Assets of the Society (exclusive of the Library and the Stock of the Journal) amounted to £623 17s. 10d., and that there were no Liabilities. The number of actual Members who had compounded before December 31st, 1899, for the payment of their Annual Subscription, was 49 ; the value of the Stock invested in the names of the Trustees of the Society was then £470 17s. 2d.

During the Session 1899-1900 the Society has lost four Ordinary Members and one Corresponding Member by death, and three Ordinary Members have been removed from the List for non-payment of their subscriptions ; on the other hand four Ordinary Members and one Corresponding Member have been

elected. The total number of Members is now 128; of these 107 are Ordinary Members and 21 are Corresponding Members.

Four Meetings have been held during the year, all in London, and (by kind permission) in the Apartments of the Geological Society, Burlington House. The attendances at these Meetings have been 17, 15, 13 and 15, respectively.

Only one Number of the Journal, published in July, has been issued since the last Anniversary Meeting. To this Professor Miers and Mr. E. G. Hartley contributed papers relative to Hitchcockite, Plumbogummite and Beudantite, belonging to the arsenate and phosphate division of minerals. Dr. Hussak and Mr. Prior described a new phosphate to which they gave the name of Florencite, and Mr. Prior further suggested that Florencite, Hamlinite, Plumbogummite (Hitchcockite), Beudantite and Svanbergite are all of them members of the same Natural Group. Mr. Hutchinson described a new mineral species, Stokesite, remarkable as being a silicate of calcium and tin. Further, Mr. Solly and Mr. Jackson gave an account of the various sulpharsenites of lead from the Binnenthal, and Mr. Prior a description of some remarkable rocks from Abyssinia. For the Abstracts in the same Number the Society is again indebted to the industry of Mr. Spencer and Mr. Herbert Smith.

The Council regrets to report that with the issue of the forthcoming Number Professor Miers will retire from the Editorship of the Journal, the duties of which post he has now undertaken for ten years to the gratification of the Society and the satisfaction of the authors of papers. The Council is glad to report that Mr. Spencer is willing to undertake the duties, and has been appointed Editor.

At the last Anniversary Meeting a Committee, consisting of Prof. Church, Mr. Scott, Mr. Beale and Mr. Fletcher, was appointed to consider the Rules of the Society; as a result of their deliberations a set of Bye-laws in which the experience of a quarter of a century is incorporated has been prepared for recommendation to the Society at this Anniversary Meeting.

On the motion of the President, seconded by the General Secretary, the Report was adopted.

Thanks were voted to the auditors (Mr. J. H. Collins and Mr. Kitto), to the Geological Society for the use of its Apartments, to the retiring Editor of the Journal after 10 years of service, and to the retiring Members of Council (Prof. Cole, Dr. Gurney, Mr. Mallet and Mr. Prior).

The Bye-laws submitted for the consideration of the Society by the Committee appointed at the last Anniversary Meeting and by the Council were amended.

On the motion of Mr. Beale, seconded by General McMahon, it was resolved that the Bye-laws as thus amended be substituted for the existing Rules: the General Secretary was instructed to insert a copy in the Minutes, and to publish a copy in the next Volume of the Journal.

The following papers were then considered:—

An improved form of Three-Circle Goniometer; by Mr. G. F. Herbert Smith, B.A.

A simple proof of the rationality of the anharmonic ratio of four faces of a zone; by Mr. Harold Hilton, B.A. (Communicated by Professor Miers.)

Sulpharsenites of lead from the Binnenthal: Part II, Rathite; by Mr. R. H. Solly, M.A.

LIST OF SERIALS IN THE LIBRARY OF THE MINERALOGICAL SOCIETY.

Librarian: Prof. W. J. Lewis, The New Museums, Cambridge.

BOUND VOLUMES.	UNBOUND PARTS.	MISSING.
Bristol Naturalists' Society, Proceedings	From Vol. III, 1880 to VI, 1891	—
Cornwall, Royal Institution, Journal	IX, 1886 to XIII (4), 1898	Part 37, 1891; Part 39, 1893
Edinburgh Geological Society, Transactions	VII, 1894–9	—
Glasgow Geological Society, Transactions	X, 1892–6	—
Mineralogical Magazine (2 copies), I, 1876 to X, 1894	XI, 1895; XII, 1900	—
Naturalist, The	1885 to 1899	—
North of England Institute of Mining and Mechanical Engineers	XXVI, 1876 to XLIX, 1900	—
Yorkshire Naturalists' Union, Transactions	I, 1878 to XXI, 1898	IX to XIX
Australian Museum (Sydney), Records	I, 9, 1891 to III, 7, 1900	—
Australian Museum (Sydney), Reports	1882 to 1899	—
New South Wales, Royal Society, Journal and Proceedings	IX, 1875 to XXXIII, 1899	XIII, 1879; XIV, 1883; XVII, 1887
New South Wales, Department of Mines, Annual Reports	1876 to 1899	1878, 9; 1882, 3; 1885; 1887–9; 1897
New South Wales, Mines and Mineral Statistics	1875 to 1880	—
New South Wales, Geological Survey, Records	II, 1890 to VI, 1900	—
New South Wales, Geological Survey, Memoirs	Nos. 1 to 9	No. 6
New South Wales, Technological Museums Reports	1883 to 1890	1887
Victoria, Mineral Statistics	1876 to 1881	—
Victoria, Reports of Chief Inspector of Mines	1874, 5; 1881	—
Victoria, Reports of Mining Surveyors	March 1875 to Sept. 1882	—
New Zealand, Geological Survey, Reports, 1874 to 1878	—	—
Canada, Geological Survey, Reports, 1894 to 1897	1879 to 1893	—

BOUND VOLUMES.	UNBOUND PARTS.	MISSING.
Nova Scotian Institute Nat. Sci., Proceedings and Transactions	IV, 4, 1877 to X, 1, 1899	V, 2 and 4; VI; VII, 1, 2
American Chemical Journal, II, 1880 to XVII, 1895	I, 1879; XVIII, 1896 to XXI, 1899	XVIII, 9; XIX, 1
American Geologist	XVII, 1896 to XXV, 1900	—
American Journal of Science, XIII [iii] 1877 to II [iv], 1896	III, 1897 to IX, 1900	—
Journal of Geology	V, 1897 to VII, 1899	V, 1
California, Annual Reports of the State Mineralogist	IV, 1884 to XIII, 1896	—
Colorado Scientific Society, Proceedings	I, 1883 to III, 1889	II, 1; III, 1
New York Academy of Sciences, Annals	1881–3	—
New York Academy of Sciences, Transactions	1881–3	—
Philadelphia Academy of Natural Sciences, Proceedings, 1877 to 1884	—	1881; 1883
Smithsonian Institution, Annual Reports, 1881 to 1895	—	—
United States Geological Survey, Annual Reports, II, 1880 to XX, 1899	—	—
United States Geological Survey, Bulletins, I, 1883 to CXXII, 1894	XVIII to XLVI; LXV to LXX; LXXXVII to LXXXIX; CXXIII to CLXII, 1899	—
United States Geological Survey, Mineral Resources, 1883 to 1893	—	—
United States Geological Survey, Monographs, I, 1890 to XXXVIII, 1899	—	—
United States Geological and Geographical Survey, for 1878 (Wyoming and Idaho), 1883	—	—
France, Société Minéralogique, Bulletin, I, 1878 to X, 1887; XVIII, 1895	XIX, 1896 to XXI, 1898	XI to XV; XVI, 8; XVII, 6 to 8; XXI, 3 to 7; XXII, 1899
Luxembourg, Publications Institut Grand-ducal (Soc. Sci. Nat.)	II, 1854 to XXIV, 1896	VI, 1863; XXI, XXII, 1892–3
Belgique, Société Géologique, Annales, I, 1874 to XXI, 1894	XVIII; XIX; XXII, 1894 to XXV, 1898	XIX, 1
Giornale di Mineralogia (Sansoni), I, 1890 to IV, 1893	V, 1894	Fasc. III, 1894
Rivista di Mineralogia e Crist. (Panebianco)	XVII, 1897 to XXIV, 1900	—
Il Nuovo Cimento, I [iv] 1895 to II [iv] 1895	III [iv], 1896 to X [iv], 1899	III, 2, 1896

BOUND VOLUMES.	UNBOUND PARTS.	MISSING.
Atti R. Accad. Lincei, Rendiconti, I, 1885 to VI, 2, 1890	IV, 2	—
Atti R. Accad. Lincei, Transunti, VII, 1883 to VIII, 1884	V, 1881	VI, 1882
Atti Soc. Toscana Sci. Nat., Memorie, III, 1877 to XIV, 1895	VIII, 1, 1886; XV, XVI	VIII, 2
Reale Comitato Geologico d'Italia, Bollettino, VIII, 1877 to XI, 1880; XVI, 1885 to XXII, 1891; XXIV, 1893 to XXVI, 1895	VII, 1876; XII, 1881 to XV, 1884; XXIII, 1892; XXVII, 1896 to XXX, 1899	—
Rendic. Accad. Sci. Napoli, III, 1889 to VIII, 1894; I [iii], 1895	II, 1888; IV, 1890; II [iii], 1890 to V [iii], 1899	II [ii], 3 to 8; IV [ii], 5; V [iii], 5
Mineralogische und Petrographische Mittheilungen, I, 1878 to XV, 1895	XVI, 1896 to XIX, 1899	—
Vienna, Geolog. Reichsanstalt, Jahrbuch, XXVII, 1877 to XLIV, 1894	XLV, 1895 to L, i, 1900	—
Vienna, Geolog. Reichsanstalt, Verhandlungen	1877 to 1899	—
Vienna, Naturhist. Hofmuseum, Annalen, I, 1886 to IX, 1894	X, 1895; XI, 1896	—
Zeitschrift f. Krystallographie und Mineralogie, I, 1877 to XXVI, 1896	XXVII, 1897 to XXXI, 1900. Rep. XI to XX; XXI to XXX	—
Zeitschrift f. Naturwissenschaften, Halle, XLIX, 1877 to LXVI, 1893	LVI, 1883; LXVII, 1894 to LXXI, 1898	—
Finland, Commission Géologique, Bulletin	I, 1895 to VIII, 1898; XI, 1900	VI; IX; X, 1899
Finland, Geol. Undersökning, Beskrifning till Kartbladet, X to XVII	I; II; XXII to XXIX; XXXV	III; IX
Upsala, Geological Inst. Univ., Bulletin, I, 1893–4	II, 1895 to IV, 1900	—
Upsala, Univ. Min.-Geol. Institt., Meddelanden, I to XV	XVI to XXII	—
Grönland, Meddelelser om, I, 1879 to XIII, 1890	XIV to XXI; XXIII, 1899	XXII, 1899
Mexico, Memorias y Revista Soc. Cient. "Antonio Alzate"	I, 1887 to III, 1890	I, pp. 363 to 418; II, 1889
S. Paulo, Bol. Com. Geog. e Geol. I, 1889 to IX, 1893	X, 1894 to XIV, 1897	XI
S. Paulo, Bol. Com. Geog. e Geol., Dados Climat., 1887 to 1892	1893 to 1897	—
Argentina, Anales Soc. Cient., VIII, 1879 to XL, 1895	XI, XII, 1881; XXIX to XXXIV; XLI, 1896 to XLIX, 1900	—

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No. 58. NOVEMBER, 1900. Vol. XII.

Petrographical Notes on the Rock-Specimens collected in the Little Island of Trinidad, S. Atlantic, by the Antarctic Expedition of 1839-43, under Sir James Clark Ross.

By G. T. Prior, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

[Read January 23rd, 1900.]

THE Little Island of Trinidad, as it is called to distinguish it from the larger island in the West Indies, is situated in the South Atlantic Ocean, about 700 miles off the coast of Brazil, in lat. 20°31′ S. and long. 29°19′ W.

According to Ross,[1] who in 1839 effected a landing on the N.W. coast, the island is a mass of volcanic matter, the rocks of which it is composed assuming the most extraordinary shapes. The most remarkable of these are the Sugar Loaf Hill on the southern and the Nine-Pin Rock on the north-western coast. The latter is described as consisting of "greenstone" (phonolite, see below), and rising to a height of 850 ft. almost perpendicularly from the sea in the form of a beautifully proportioned column. It is attached on the land side to a ridge of hills, two or three hundred feet high, also composed of "greenstone," like the perpendicular

[1] *A Voyage of Discovery and Research in the Southern and Antarctic Regions during the years 1839–43.* London, John Murray, 1849.

cliffs which opposed an insuperable barrier between the beach on which the landing was effected and the interior of the island.

Further details concerning the extraordinary physical features of this desolate volcanic island are given by E. F. Knight,[1] who conducted an expedition there in search of a treasure supposed to have been hidden by pirates. According to Knight, Trinidad is a precipitous mass of barren volcanic rock studded with sharp, needle-like peaks, the highest of which is about 3,000 ft. above sea-level. It is about 15 miles in circumference, and is surrounded by sharp coral reefs. The conical hill on the S.E. known as the Sugar Loaf is about 1,500 ft. high. It is described by Knight as "apparently of grey granite," but, like the Nine-Pin Rock it most probably consists of phonolite.[2]

The rock close to it, called from its peculiar shape "Noah's Ark," is 800 ft. high, and is referred to as "probably a crater." Certainly, in East Bay, in the neighbourhood of these rocks, the signs of volcanic activity were more evident than elsewhere, in a succession of streams of black basaltic lava, ledges of which extend far out to sea. A peculiarity of the island insisted on by Knight is that it is nowhere solid, but rotten throughout. The lower slopes on the western side are composed of *débris*, with loose stones of every size easily dislodged, and even the columns of basalt forming precipitous walls rising hundreds of feet high above this *débris* are described as rotten and crumbling away under the tread, so that the ascent to the grass-covered plateaux in the centre of the island was a work of great difficulty.

The rock-specimens collected by Ross serve to illustrate these descriptions of the island. With the exception of two rolled pebbles (probably from the beach) of radiolarian chert and coralline limestone, they are all of volcanic material. They are mostly of phonolite, but comprise also examples of basaltic rocks, including nephelinite and limburgite, and of tuffs and agglomerates made up of fragments of both phonolites and basalts.

Phonolites.

The phonolites in appearance and structure are of various types, although in general characterised by the size and great number of the abundant phenocrysts of nepheline, as well as by the large amount of

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[1] *The Cruise of the "Falcon."* London, Sampson Low, &c., 1887. *The Cruise of the "Alert."* London, Longmans, Green & Co., 1890.

[2] The phonolite Peak of Fernando Noronha was originally described as of granite (*Quart. Journ. Geol. Soc.* xlii, 1872, p. 43).

the pyroxenic constituent ægirine-augite. They are therefore somewhat darker and more strikingly porphyritic than the ordinary type of phonolite, and some, by decrease in the felspathic constituent and gradual replacement of the grass-green ægirine-augite by purplish augite, approach to nephelinites.

As already mentioned, the "greenstone" of the Nine-Pin Rock in Ross's account is probably phonolite and not basalt. Dr. McCormick, the surgeon on board the *Erebus*, in his book, *Voyages of Discovery in the Arctic and Antarctic Seas, &c.* (London, Sampson Low, 1884) describes on one side of the Nine-Pin Rock a dyke of "basalt," and on the other a larger one of "greenstone," thus distinguishing between the two. The large dyke of "greenstone" is stated to exhibit on its surface a singular mammiform appearance.

One of the specimens of phonolite (75355) in the collection answers precisely to this description. It is a dark greenish-brown rock with greasy lustre and splintery fracture, with a weathered surface covered with warty mammiform protuberances as described by McCormick.

Under the microscope are seen large porphyritic nephelines with small ægirine-augites and, very sparingly, sanidine and sphene in a fine-grained base of lath-shaped felspars, ægirine-augite and nepheline.

The nepheline phenocrysts are in very sharply-defined hexagonal (showing in convergent light a negative uniaxial figure) and rectangular sections: they are clear and unaltered, and include small crystals of ægirine-augite, sphene and magnetite. In one hexagonal section stages of growth are marked by a series of lines of dark inclusions parallel to the outer edges.

Sanidine is only represented amongst the phenocrysts by one or two Carlsbad twins.

The ægirine-augite is in large amount in small well-defined prismatic crystals, showing pleochroism a = grass-green; b = dull-green; c = bright brownish yellow with a tinge of red. The maximum extinction in prismatic sections does not exceed 30°. Some of the larger phenocrysts have purple centres.

Hornblende is represented by a few corroded deep brownish-red sections with the pleochroism of barkevicite or basaltic hornblende. These show signs of being partly re-absorbed, and have borders of magnetite grains, in one or two cases fringed with ægirine-augite. Small rounded patches of an aggregate of magnetite grains and reddish-brown hornblende, surrounded by a zone of ægirine-augite, are in all probability pseudomorphs after hornblende crystals.

The sphene is in sharply-defined colourless characteristic lozenge-shaped crystals.

One or two altered hexagonal sections are probably to be referred to nosean.

The groundmass, showing well-marked flow-structure, consists of felspar laths with straight extinction, needles of ægirine-augite, and nepheline in rectangular and hexagonal sections. It is rendered rather dense by dusty brown interstitial matter.

A pale green rock (No. 75349), with greasy lustre, markedly porphyritic, with large crystals (up to 5 mm. in length) of sanidine and nepheline, is in appearance more like an ordinary phonolite. It contains the same minerals as the preceding, but is much more porphyritic, the phenocrysts being more numerous, and in the case of the ægirine-augite larger, and the groundmass much finer-grained and showing no flow structure.

The pyroxenic constituent is in large amount, both as small prismatic crystals in the base and as sharply-defined phenocrysts. It consists for the most part of grass-green to yellow ægirine-augite, but some of the sections are pleochroic (purplish brown to yellow) augite, while others show purple centres with green borders, and one has a green centre and border with a purple zone between.

The section shows a coarse-grained patch of orthoclase and nepheline with prismatic ægirine-augite. Similar patches have been recorded in phonolites from Fernando Noronha, and have been regarded as fragments of the nepheline-syenite magma.[1]

A still more porphyritic type (No. 75353) shows large phenocrysts of sharply-defined nephelines and rounded, partially re-absorbed, sanidines, with smaller augites (both purple and grass-green), noseans (showing six-rayed stars of inclusion) and sphenes, in a pale brown very fine-grained base crowded with minute ægirine-augite microliths. Some of the felspar phenocrysts show very fine twin striations suggestive of anorthoclase. A phonolite from Leao, Fernando Noronha, presents very similar characters.

A specimen (No. 75348) of a somewhat camptonitic type is a pale greenish-grey rock with small vesicular cavities filled with zeolites, showing no porphyritic nepheline or felspar, but only long prismatic augites with a few larger hornblendes. Under the microscope the porphyritic augites are seen to be mainly of the purplish titaniferous kind,

[1] *Am. J. Sci.* XXXVII, 1889, p. 185.

and the hornblendes, in almost as large amount as the augites, are of the same type as in the preceding rocks, and have generally a mantle of green augite with magnetite. Nepheline is present in a few small rectangular sections much altered. Sphene and altered noseans are fairly plentiful. Apatite occurs in small hexagonal sections enclosed in the hornblende and augite. Only one phenocryst of sanidine was observed in the slide. The fine-grained groundmass consists of interlacing minute lath-shaped felspars with altered nosean and some granular augite: some clear isotropic patches are probably analcime.

This slide also contains a coarse-grained patch (about 4 mm. square) of nepheline and lath-shaped Carlsbad twins of felspar, with a little ægirine-augite.

A specimen (No. 75358) approaching more closely in structure the ordinary type of phonolite than any of the preceding, is a greenish-brown somewhat altered rock showing to the lens only small prismatic phenocrysts of sanidine. In the section besides these sanidines (in Carlsbad and Baveno twins) are one or two large altered nephelines and a little ægirine-augite. The groundmass consists of lath-shaped felspars with trachytic flow structure and much ægirine in small prismatic crystals, showing approximately straight extinction and compensating with the quartz wedge along their length (a—axis of indicatrix nearly coincident with the crystallographic axis c).

Phonolite-Nephelinites.

A dark greenish grey to black very compact rock (No. 75346), showing porphyritic nephelines and an occasional large sanidine, has characters intermediate between a phonolite and a nephelinite. It consists of phenocrysts of purplish-green augite in large amount, a little basaltic hornblende similar to that in the preceding rocks, and a few large nephelines with sphene and apatite in a base composed of altered nephelines with small prismatic ægirine-augites and some felspar laths. The nephelines, unlike those in the phonolites previously described, are for the most part corroded and rounded (in some cases presenting perfectly circular outlines), and are often crowded with gas-pores.

Hornblende, mostly nearly re-absorbed, is not present in large amount, but the section contains dark patches (in one case over $\frac{1}{2}$-in. square), consisting of an aggregate of purplish and green augite, deep brownish-red pleochroic hornblende, much opaque iron-ore (magnetite?), with apatite and sphene, which may represent original hornblende crystals

one of these patches had a roughly crystalline outline with two faces meeting at an angle of about 124°.

A specimen (No. 75341) of a dark-grey to deep reddish-brown compact rock showing porphyritic crystals of augite and hornblende, generally small, but in the case of the hornblende sometimes reaching 5 mm. in length, shows a closer approximation to a nephelinite. It consists of a base of nepheline in large plates and indefinite crystals with only a little felspar, forming a sort of paste in which are distributed augites in large amount, hornblendes, sphene and apatite, with some magnetite and ilmenite. The augites and hornblendes have similar characters to those of the preceding rock. The pleochroism of the hornblende was similar to that of barkevicite, viz. a = pale yellowish brown; b = deep reddish-brown; c = deep brown, nearly opaque. Prismatic sections showing only one cleavage gave extinctions as high as 13°, and octagonal sections showed the two cleavages inclined at an angle of about 124°. The apatite was so crowded with gas-pores as to be nearly opaque.

Limburgites.

These dense black basaltic-looking rocks (Nos. 75352 and 75333) are seen under the microscope to consist of small porphyritic augites, and in smaller amount of olivine, with magnetite, in a dense brownish-red glass, containing microliths of augite. The augite phenocrysts are very pale purple, generally with a green centre. One or two of the larger crystals had a centre consisting of an aggregate of magnetite grains and a deep brown hornblende, and are the result probably of the re-absorption of an original hornblende crystal. One or two rounded grains of reddish-brown basaltic hornblende are present in the slide. The augite and hornblende phenocrysts are therefore somewhat similar in character to those in the preceding nephelinites.

The olivine is clear and fresh, and occurs generally in long prismatic crystals. One or two corroded grains and irregular crystals of olivine have attachments of augite and hornblende on the corners and filling up cracks.

A patch of grass-green ægirine-augite grains with sphene has probably been derived from the phonolites.

Another specimen (No. 75364) of dense black basaltic rock, with a rough glassy surface, shows in section the passage (from the surface inwards) from a brown glass, with augite microliths, in which are distributed crystals of clear fresh olivine in large amount, to a rock consisting of porphyritic olivines in a dense base almost opaque from separation of

magnetite and crowded with radiating groups of small pale purple augites. In the intermediate part the augite microliths are surrounded by deep halos of magnetite, and the intervening glass is a clear pale yellow.

Volcanic Agglomerate.

A specimen of volcanic agglomerate (No. 75360) contains, besides fragments of nepheline, felspar, ægirine-augite, and phonolite, also fragments of more basic rocks, some of them showing long prismatic crystals of basaltic hornblende, and presenting a structure very similar to that of the dyke rocks from Fernando Noronha, which were described by the author (*Min. Mag.* XI, 1897, 171) as related to the monchiquites of Rosenbusch.

The only specimens not of volcanic origin were fragments, probably from the beach, of *coralline limestone* containing pebbles of phonolite, and a rounded pebble of *radiolarian chert.*

The characters of these rocks, as well as many of the geological features of the island, such as the remarkable peaks of phonolite associated with basaltic lavas, suggest analogies between Trinidad and the island of Fernando Noronha off the coast of Brazil, a thousand miles to the north, so that it appears possible that the two islands owe their origin to a very similar, if not contemporaneous, volcanic outbreak.

In Fernando Noronha, as Branner[1] states, the original lofty central portion has been denuded away until only the great Peak and its smaller companions remain to suggest the formal elevation of the group. In Trinidad the disintegrating agents have not effected so radical a change. The lofty inaccessible peaks of the central portion still remain, but Knight's account suggests that the time when these will have been levelled cannot be very far distant, for denudation appears to be going on at a very rapid rate, and enormous landslips are of frequent occurrence.

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[1] *Am. J. Sci.* XXXVII, 1889, p. 146.

On some remarkable composite crystals of copper pyrites from Cornwall.

By Professor W. J. Lewis, M.A., and A. L. Hall, B.A.

[Read January 23rd, 1900.]

During a recent visit to Cornwall the attention of Professor Lewis was directed by Mr. James Wickett to some composite crystals of copper pyrites recently found in one of the deep mines in the neighbourhood of Redruth. On the specimens acquired by the Cambridge Museum about thirty crystals show this composite growth, which causes the crystals to resemble ill-developed pentagonal dodecahedra of iron pyrites. Many of them are much tarnished, and some show purple and blue colours due to thin films: and they are deposited together with small brilliant crystals ($\{100\}$ and $\{111\}$) of hæmatite on a matrix of chalybite, which at the surface is developed in minute lenticular crystals.

Simple crystals.

The habit of most of the crystals is notably sphenoidal, owing to the predominance of two forms, which are in some cases a very obtuse sphenoid and a very acute one; in other cases the obtuse sphenoid is replaced by the pinakoid or by the pinakoid alternating with the faces of an obtuse sphenoid. The obtuse sphenoid is either $l=\kappa\{114\}$, or $\lambda=\kappa\{229\}$, or $\gamma=\kappa\{115\}$, or $\beta=\kappa\{118\}$. The acute sphenoid is one of the following: $\rho=\kappa\{553\}$, $r=\kappa\{332\}$, $t=\kappa\{221\}$, $f=\kappa\{552\}$, $u=\kappa\{441\}$, $F=\kappa\{551\}$, $T=\kappa\{22\bar{1}\}$.

The faces of the above sphenoids, of the pinakoid $c\{001\}$, and in many cases those of the prism $m\{110\}$ are deeply striated in a direction parallel to the edges in which faces in a vertical zone intersect. This striation has rendered it very difficult to determine the symbols of the forms. Another difficulty was likewise encountered, for measurements between tautozonal faces on opposite sides of the principal axis often differed by 4° or 5°; and it was occasionally observed that on one side the face (441) or (551) is largely developed, whilst on the other side the face $(\bar{1}\bar{1}0)$ is the conspicuous one. The sphenoid $o=\kappa\{11\bar{1}\}$ is generally present, but the faces are always very small; they are, however, fairly free from striæ, and measurements from them to faces in adjacent vertical zones have

served to check the determination of the symbol of these latter faces. The sphenoid $T=\kappa\{22\bar{1}\}$ is often present, but the faces are in all cases very dull.

Faces of one or both of the pyramids $e\{101\}$, $z\{201\}$ often occur as small triangles modifying the coigns on the horizontal edges in which the faces of the obtuse sphenoid or pinakoid meet the faces of the acute sphenoid. The faces z are striated each in a direction which seems to be parallel to the edge of intersection with an adjacent face (111); each face e in a direction parallel to the adjacent face $(1\bar{1}1)$. The faces of these forms are usually bright, but the striæ have much interfered with their usefulness in determining the symbols of particular faces or in confirming the twin-law.

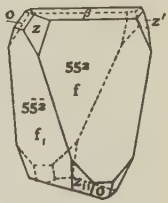

FIG. 1.

Fig. 1 represents a very small crystal on which the forms $\beta=\kappa\{118\}$, $f=\kappa\{552\}$, $o=\kappa\{1\bar{1}1\}$, $z=\{201\}$ were definitely determined. Close inspection of the coigns at which the faces z appear reveals the presence of two or three additional forms, the faces of which are too striated to admit of accurate measurement. Measurements of the angles between faces of one of these forms and those of z accord fairly well with the form being $\kappa\{825\}$; the faces of another form belong to $e\{101\}$. The faces of these two forms, being very subordinate, have been omitted in the drawing. The faces z are striated parallel to the edges of intersection with the adjacent faces of $\kappa\{825\}$.

A second crystal measured shows the forms $\lambda=\kappa\{229\}$, $\gamma=\kappa\{332\}$, $m\{110\}$, $T=\kappa\{22\bar{1}\}$. The coigns at which faces λ, r and T meet are modified by well developed faces σ, which are striated in the same way as the faces z in the first crystal. The measurements between homologous faces σ do not agree with those of $e\{101\}$; and the form nearly accords with $\{1, 12, 12\}$. The same displacement of the faces from the position of those of the pyramid e was also observed on one of the twin-crystals described further on.

In a third crystal the faces of the pinakoid $c\{001\}$ and of the sphenoid $F=\kappa\{551\}$ are largely developed; those of the sphenoid $\lambda=\kappa\{229\}$ are narrow planes modifying the obtuse edges $[c\ F]$. The faces of the sphenoid $o=\kappa\{1\bar{1}1\}$, and of the pyramid $e\{011\}$ are very small. The symbols of the faces λ are deduced from measurements of the angles $o\wedge\lambda$; for the faces λ and of the pinakoid are much striated parallel to their common edge. The face c in this and other crystals, on which the inclination to other faces was measured, seems generally to be a good deal

displaced. Thus, $c\wedge\lambda'(\bar{2}\bar{2}9)$ was found to be 16°4′, and $c\wedge\lambda(229)$ to be 18°48′. That it is the face c which is displaced was shown by measurement of the angles $o\lambda$ and $o\lambda'$; for $o\lambda = 56°7'$ and $o\lambda' = 56°20'$.

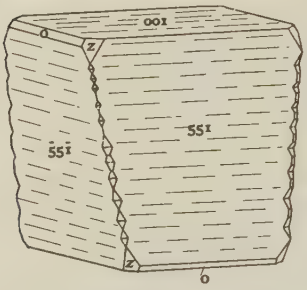

Fig. 2.

Fig. 2 represents a crystal having a somewhat cubic habit. The forms present are, according to measurements made with a contact-goniometer, taken to be $\kappa\{551\}$, $\{001\}$, $\{201\}$, $\{100\}$. The faces o and z are very small; and pairs of the latter alternate with faces of the tetragonal prism $\{100\}$ in such a way as to give the appearance of a deeply furrowed face which truncates the slanting edges of the acute sphenoid. The relative dimensions of these alternating faces to those of the sphenoid are much exaggerated in the drawing. In some crystals of this habit the sphenoid seems to be $\kappa\{441\}$ or $\kappa\{552\}$, and occasionally the faces of the prism $\{110\}$ are also present. In a few cases the crystals have an irregular development, owing to the fact that the predominant faces consist of two or three faces of the acute sphenoid associated with one or two faces of the prism $\{110\}$. Thus we get the crystal sometimes bounded by the pinakoid $\{001\}$, a pair of opposite faces of the sphenoid, such as $(5\bar{5}\bar{2})$, $(\bar{5}5\bar{2})$, and a pair of opposite prism-faces (110), $(\bar{1}\bar{1}0)$. A crystal of this type is shown in Fig. 3, which gives approximately the relative sizes of the faces. The crystal is an acute wedge which is much elongated along the edge of intersection of the two predominant faces of the sphenoid $\kappa\{552\}$.

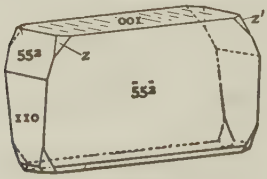

Fig. 3.

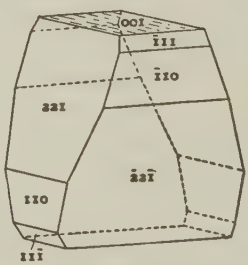

Fig. 4.

Fig. 4 represents in equable and normal development the general habit resulting from the combination of forms $\{001\}$, $\kappa\{221\}$, $\{110\}$, $\kappa\{11\bar{1}\}$. But the forms are commonly unequably developed; and, as illustrated by Fig. 8, the faces of $\kappa\{221\}$ are sometimes interrupted, and a prism-face (110) is interposed between two portions of the same face (221).

Twin-crystals.

The twin-axis is the normal to a face of the sphenoid $o = \kappa\{1\bar{1}1\}$.

The peculiar resemblance to iron pyrites of the most remarkable of the twins arises from the great development of the obtuse sphenoid. In the twins of this character the individuals are mostly in juxtaposition; but the combination-surface is rarely a definite plane, and there is a certain amount of interlocking, and in many cases portions of one individual protrude beyond the other. The depth of striation also causes a considerable irregularity in the edges common to the two individuals. If a crystal like one of those represented in Figs. 1 and 4 is bisected by a central plane perpendicular to the twin-axis, the edges in which the plane of section meets the faces will not be all congruent after one portion has been turned through 180° about the twin-axis. Supposing the normal $(1\bar{1}1)$ to be the twin-axis, the two prism-faces (110) and $(\bar{1}\,\bar{1}0)$ which are parallel to it change places, and these faces will be co-planar in the twin. Again, the faces in the zone $[001, 1\bar{1}1]$, which includes the face $o(1\bar{1}1)$, are tautozonal in the twin; and any pair of such faces which meet intersect in a line parallel to the edges of the zone. Thus, in the somewhat idealised doublet shown in Fig. 5, the face $T(\bar{2}21)$ intersects $i_{,}(1\bar{1}\bar{4})$ in a re-entrant edge parallel to the edge $[l_{,}l_{,,}]$. In this doublet the two faces 221 and $(\bar{2}\bar{2}\bar{1})$, which belong to the complementary sphenoids $\kappa\{221\}$ and $\kappa\{22\bar{1}\}$, are represented as equably developed on opposite sides of the combination-plane, which has been taken to be $\{1\bar{1}1\}$ perpendicular to the twin-axis; and this is very nearly the case in the quartet of which three individuals are shown in Fig. 6. In some cases the individuals are juxtaposed approximately along a plane which belongs to a different form in each individual. Thus in several of the twins the combination-plane is $t(221)$ of one individual and $c(001)$ of the other. In twins of this character the individual having c for combination-plane is usually smaller than the other, and is often reduced to such small dimensions that it looks much like a limpet deposited on a relatively large (221) face of the large individual.

In other cases the one individual completely penetrates the other, the imbedded individual being always small compared with the other. An instance of this case of the twin is shown in Fig. 8, where a striated face $c_{,}$ appears as an irregular patch in the face $t(221)$, with which $c_{,}$ is practically co-planar; the theoretical angle between the two being 1°4′. On the face adjacent to t the imbedded twin-individual appears as a wedge inserted in the crystal. Occasionally the patch forms, as it were, an

island in the face t: such patches are very noticeable, for the striæ on c, are at right angles to those on the face t and to those on the face c which is inclined to the patch at an angle of 71°20′.

The twin-law was established by measurements of the angles $l \wedge l_{,}$, $l' \wedge l_{,}$, $l \wedge l_{''}$, $l' \wedge l_{''}$, $o \wedge o_{,}$, $o \wedge o_{''}$; and of a zone $[l_{''} l_{,} l'1]$, common to two individuals, which are united to a middle one about the homologous twin-axes $1\bar{1}1$ and $\bar{1}11$ respectively. The measurements in this zone were:—$t_{''} l_{''} = 50°21'$, $l_{''} l_{,} = 38°3'$, $l'_{,} l = 103°25'$, $l' l = 38°5'$, $l\,t = 50°13'$, $lm = 72°12'$. The face l being (114), the twin-law gives $l_{,} \wedge l' = 104°16'$, and t being (221), $t_{''} \wedge t = 283°12'$, whilst the sum of the angles from $t_{''}$ to t is 280°7′, and again $t_{''} \wedge m = 302°56'$, measured 302°6′. The measured angle $l \wedge l_{,} = 114 \wedge (1\bar{1}\bar{4})$ was found to be 55°0′, and $l' \wedge l' = \bar{1}\bar{1}4 \wedge (1\bar{1}\bar{4})$ to be 54°43′, whilst the computed value is 54°34′. The measured angle $l \wedge l_{''} = 114 \wedge (\bar{1}1\bar{4})$ is 90°8′, $l' \wedge l_{''} = \bar{1}\bar{1}4 \wedge (\bar{1}1\bar{4})$ is 90°1′; the computed value being 90°30′. Further, $o \wedge o_{,} = 1\bar{1}1 \wedge (\bar{1}\bar{1}\bar{1}) = 109°19'$, $o \wedge o_{''} = 1\bar{1}1 \wedge (11\bar{1}) = 110°25'$; the computed value being 109°54′.

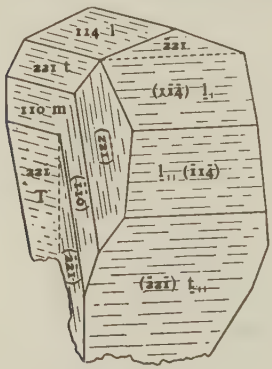

Fig. 5.

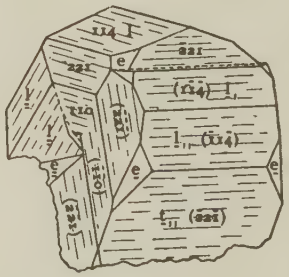

Fig. 6.

Fig. 6 represents a twin in which three unequal individuals are united to a central one about homologous axes. The first individual (that to the right) is twinned to the upright one about the normal $(1\bar{1}1)$; the second (that to the front) about the normal $(11\bar{1})$; and the third, which is very small and has its faces l tautozonal with those of the individual to the right, is twinned to the upright one about $(\bar{1}11)$.

Two individuals are frequently united to a larger one in the manner just described for the first and third individuals; *i.e.* the latter are twinned

to the central individuals about the normals to faces $(1\bar{1}1)$ and $(\bar{1}11)$, which are tautozonal with (001) of the larger crystal. The measurements in such a zone have been already given.

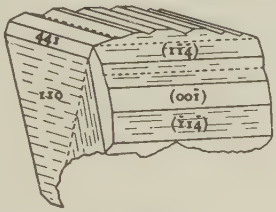

Fig. 7.

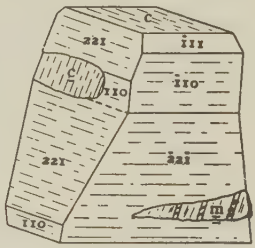

Fig. 8.

Fig. 7 shows an instance of a doublet in which but few forms are present. The pinakoids are largely developed, but very rough. They are mainly composed of ridges formed by alternating faces of an obtuse sphenoid, which may be $\kappa\{118\}$, or $\kappa\{114\}$, &c. The acute sphenoid has been taken to be $\kappa\{441\}$, and the composite face shown is apparently (110); but the crystal has only been measured by a contact goniometer, for the faces are rough, dull and much tarnished. This twin represents an intermediate stage between those of the type shown in Figs. 5 and 6 and those, like Fig. 8, in which the twin is only shown by a patch imbedded in a face t (221) of an apparently simple crystal.

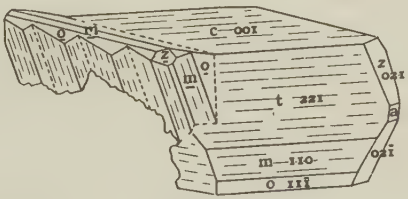

Fig. 9.

Fig. 9 shows a twin of a different habit. This twin differs so much from all the others that we at first thought we had to deal with two different laws; but measurements easily established that $(1\bar{1}1)$ is the twin-face. The drawing shows with fair approximation the relative dimensions of the faces.

A second wedge of inserted matter is shown on the face $(\bar{2}2\bar{1})$ of Fig. 8 protruding into the crystal. At the back of the crystal a horizontally striated patch is observed; and the patch consists of a face c, which seems co-planar with the face $t'(\bar{2}\bar{2}1)$. If the faces t'' and c were

approximately co-planar, the striæ on the latter should be in a vertical plane; and it seemed as if the inserted matter had further undergone a quarter-revolution about its principal axis. Careful examination convinced the authors that the appearance of the two faces being co-planar was deceptive, and that the inserted matter has been turned through 180° about the normal $(11\bar{1})$. This is shown by the fact that the coarse markings on m are practically parallel to the face $t(221)$; and the face c to which they are parallel is therefore really parallel to t, and not to t'.

In drawing asymmetric twins such as those which we have described there is some difficulty in determining the directions of the edges in which non-homologous faces meet. Such edges are often most easily found by taking approximate values for the parameters which give rational indices to the faces of the rotated crystal, when the latter is referred to the axes of the fixed individual. Mr. R. W. H. T. Hudson,[1] B.A., of St. John's College, has been good enough to determine a formula which gives the position of a face-normal after a rotation of 180° about any twin-axis, and also a more generalised one which applies when the angle of rotation is θ. In applying his general formulæ to the twins of copper pyrites, the crystal is taken to have rectangular axes and equal parameters; *i.e.* to be, as far as computations are concerned, cubic. The twin-axis being now taken to be $(1\bar{1}1)$, and $(h_1k_1l_1)$ being the symbol of a face or normal which is (hkl) before a semi-revolution about $(1\bar{1}1)$, then the new indices are given by the equations:—

$$\left.\begin{aligned} 3h_1 &= -3h+2(h-k+l),\\ 3k_1 &= -3k-2(h-k+l),\\ 3l_1 &= -3l+2(h-k+l),\end{aligned}\right\} \ldots\ldots (1)$$

In the case of copper pyrites the new symbol of any face (hkl) can be also easily found from the above-mentioned approximation to the parameter c, and the following two relations:—(1) That the face in its new position is in a zone with o and its original position; (2) That its inclination to o remains unchanged. Hence (hkl) being the original face, and $(h_1k_1l_1)$ its symbol after a semi-revolution about $(1\bar{1}1)$, we have the equations:—

$$\begin{vmatrix} h_1 & k_1 & l_1 \\ 1 & \bar{1} & 1 \\ h & k & l \end{vmatrix} = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2);$$

[1] Mr. Hudson's formulæ are given in the *Mineralogical Magazine*, XII, p. 345, 1900.

$$\text{Cos } oP = \frac{h-k+l}{\sqrt{3}\sqrt{h^2+k^2+l^2}} = \frac{h_1-k_1+l_1}{\sqrt{3}\sqrt{h_1^2+k_1^2+l_1^2}} \quad \ldots\ldots\ldots\ldots (3).$$

By substituting in (3) the value obtained from (2) of one of the unknown indices—k_1 (say)—in terms of the two others, a quadratic equation in the two indices h_1, l_1 is found. The roots of this equation are easily obtained; for it must break up into two linear factors, one of which must be $h_1 l - h l_1$. Thus for $l_{,}(1\bar{1}\bar{4})$ equation (2) gives—

$$h_1 + k_1 = 0 \quad \ldots \quad \ldots \quad ;$$

and equation (3) becomes—

$$(4h_1 + l_1)\,(8h_1 + 7l_1) = 0.$$

Hence the face in its new position has the symbol $(\bar{7}78)$.

The following table gives the position after a semi-revolution about $o(1\bar{1}1)$ of a face having the symbol given in the second column:—

	Originally.	After rotation.		Originally.	After rotation.
$l_{,,}$	$\bar{1}1\bar{4}$ ...	*$\bar{1}10$*	$o_{,,}$	$\bar{1}\bar{1}\bar{1}$ ...	*151*
$c_{,}$	$00\bar{1}$ ...	*$\bar{2}21$*	$A_{,}$	010 ...	*212*
$l_{,}$	$1\bar{1}\bar{4}$ ...	*$\bar{7}78$*	e	101 ...	*$1\bar{4}1$*
$t_{,}$	$2\bar{2}\bar{1}$ ...	*001*	m	110 ...	*$\bar{1}\bar{1}0$*
m	$1\bar{1}0$ ...	*$1\bar{1}4$*	t	221 ...	*$4\bar{8}\bar{1}$*
			l	114 ..	*$5\bar{1}\bar{1}\bar{4}$*

The principal angles measured on the crystals are given in the following table: the striation and tarnish of the faces render it impossible to get really trustworthy measurements.

Angles measured.		No. of Observations.	Extremes.	Mean.	Calculated.
oc	111 ∧ 001	11	53°17′ — 54°45′	54° 8′	54°20′
ll'	114 ,, $\bar{1}\bar{1}4$	6	37 55 — 39 56	38 31	38 25
$\lambda\lambda'$	229 ,, $\bar{2}\bar{2}9$	8	32 17 — 36 10	34 24	34 24
$\gamma\gamma'$	115 ,, $\bar{1}\bar{1}5$	2	29 23 — 29 53	29 38	31 8
$\beta\beta'$	118 ,, $\bar{1}\bar{1}8$	1	..	19 34	19 46
rr'	332 ,, $\bar{3}\bar{3}2$	2	126 59 —128 4	127 32	128 52
cr	001 ,, 332	6	62 53 — 65 0	63 49	64 26
$\rho\rho'$	553 ,, $\bar{5}\bar{5}3$	1	..	131 57	133 24
$c\rho$	001 ,, 553	4	65 35 — 67 48	66 48	66 4
tt'	221 ,, $\bar{2}\bar{2}1$	1	..	138 54	140 32
ct	001 ,, 221	8	69 15 — 71 42	70 20	70 16

Angles Measured.	No. of Observations.	Extremes.	Mean.	Calculated.
ff' 552 ∧ $\bar{5}\bar{5}2$	1	..	147°22′	147°58′
cf 001 ,, 552	2	72°56′ — 75°45′	74 20	73 59
cF 001 ,, 551	1	..	81 6	81 50
cu 00$\bar{1}$,, 44$\bar{1}$	1	..	101 37	100 10
cm 001 ,, 110	1	..	90 32	90 0
om 1$\bar{1}$1 ,, 1$\bar{1}$0	7	35 13 — 37 44	36 39	35 40
mT 110 ,, 22$\bar{1}$	1	..	22 25	19 44
$l\rho$ 114 ,, 553	3	47 16 — 48 41	48 2	47 30
$tt_{,}$ 221 ,, 2$\bar{2}\bar{1}$	1	..	97 1	96 33
ee' 101 ,, 011	1	..	59 27	59 30
ee'' 101 ,, $\bar{1}$01	1	..	89 50	89 9
ae 100 ,, 101	1	..	45 45	45 25
zz' 201 ,, 0$\bar{2}$1	6	76 30 — 79 43	78 11	78 11
oz 1$\bar{1}$1 ,, 201	5	35 44 — 39 50	38 19	39 6
mz 1$\bar{1}$0 ,, 201	1	..	50 38	50 54
az 100 ,, 201	2	27 26 — 27 33	27 29	26 54
zz'' 201 ,, $\bar{2}$01	1	..	125 11	126 11
el 101 ,, 114	4	31 17 — 33 48	32 3	33 17
el' 101 ,, $\bar{1}\bar{1}$4	3	59 10 — 60 2	59 44	59 22
$\xi\xi'$ 825 ,, 285	1	..	51 59	52 0
$o\lambda$ 1$\bar{1}$1 ,, 229	2	56 7 — 56 20	56 13	56 9
oe 1$\bar{1}$1 ,, 101	1	..	35 45	35 4
oe' 1$\bar{1}$1 ,, 011	1	..	89 14	89 18
or 1$\bar{1}$1 ,, 332	1	..	76 16	75 26
er 101 ,, 332	1	..	41 46	40 58
$\sigma\sigma'$ 1,12,12 ∧ 12,1,12	2	53 37 — 55 24	54 30	54 2
$\sigma\sigma''$ 1,12,12 ,, $\bar{1}$,$\bar{1}\bar{2}$,12	2	89 25 — 89 50	89 38	89 20
$\sigma\sigma'''$ 1,12,12 ,, $\bar{1}\bar{2}$,$\bar{1}$,12	4	63 0 — 65 43	63 52	64 54
$m\sigma$ 110 ∧ 1,12,12	1	..	57 29	57 33
$oo_{,,}$ 1$\bar{1}$1 ,, (11$\bar{1}$)	1	..	109 19	109 52
$oo_{,}$ 1$\bar{1}$1 ,, ($\bar{1}\bar{1}\bar{1}$)	1	..	110 25	
$ll_{,}$ 114 ,, (1$\bar{1}\bar{4}$)	1	..	55 0	54 34
$l'l_{,}$ $\bar{1}\bar{1}$4 ,, (1$\bar{1}\bar{4}$)	1	..	54 43	
$ll_{,,}$ 114 ,, ($\bar{1}$1$\bar{4}$)	1	..	90 8	90 30
$l'l_{,,}$ $\bar{1}\bar{1}$4 ,, ($\bar{1}$1$\bar{4}$)	1	..	90 1	

On Grassmann's method of axial representation, and its application to the solution of certain crystallographic problems.

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[Read April 3rd, 1900.]

GRASSMANN, in his Memoir, *Zur physischen Krystallographie und geometrischen Combinationslehre*, published in 1829, referred a crystal to three face-normals—*rays*—as axes of reference; the parameters being the edges along the axes of a parallelepiped having for diagonal a definite length of a known normal which is not co-planar with any pair of the axial rays. Any other normal is then represented as the diagonal of a similarly formed parallelepiped having for its edges along the axes lengths which are rational multiples of the parameters. Grassmann gave no formulæ for finding in general the indices of face-normals from measurements of the angles on the crystal; nor for determining the angles from the crystal-elements and indices. Frankenheim (Crelle's *Journal f. Mathematik*, VIII, p. 178, 1832) gives an expression for the cosine of the angle between any two rays, but his expression is not in a form such as is now usually adopted. Miller, in his memoir on the method (*Proc. Camb. Phil. Soc.* II, p. 75, 1868) limited himself to a few general problems relating to zones. The space which could be spared to the subject in my *Treatise on Crystallography*, 1899, only allowed me to give the relation connecting the ray-parameters with those of a crystal referred to zone-axes. But the inclination of any ray to the reference-rays and to any other ray can be easily found by the process adopted in Chapter XIX, Arts. 9, 10, 11, 13 and 14 of my *Treatise* for the similar relations connecting the direction of a line with axes which are edges of the crystal. The relations obtained when the crystal is referred to axial rays are more immediately applicable to the angles found by goniometric measurement, and are in many respects simpler than the relations given in the above mentioned articles. As, further, Grassmann's axial representation gives many elegant expressions applicable to the solution of problems which occur in the determination of the face-symbols and angles of crystals, I have thought that it may prove useful to establish some of the principal relations.

We shall throughout assume that the same three faces are selected to give the axial system, the axial rays being parallel to their normals, and the ordinary axes to their edges of intersection. We shall take Ox, Oy and Oz to be the rays which are, respectively, perpendicular to the faces (100), (010) and (001). We shall denote by OG the parametral ray (111), and shall suppose it to be perpendicular to the face (111) referred to zone-axes. We shall denote the ray-parameters by a, b, c, and the angles between the axial rays by α, β, γ. The corresponding parameters and angles, when the crystal is referred to zone-axes, will be denoted by a, b, c, α_1, β_1, γ_1. Any ray (hkl) of the crystal is then given by the equations—

$$\frac{x}{ha}=\frac{y}{kb}=\frac{z}{lc} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1);$$

and the ray-parameters are connected with those referring to zone-axes by the equations—

$$\frac{aa}{\sin\alpha}=\frac{bb}{\sin\beta}=\frac{cc}{\sin\gamma} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2);$$

or by their equivalents—

$$\frac{aa}{\sin\alpha_1}=\frac{bb}{\sin\beta_1}=\frac{cc}{\sin\gamma_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2^*).$$

Prop. 1. To express the length of a given ray (hkl) in terms of the indices, ray-parameters, and the angles between the axial rays.

Let $OLPN$, Fig. 1, be the parallelepiped, having OP for diagonal, and for edges along the axes the lengths :—

$$OL=FM=ha,\ OM=LF=kb,\ ON=PF=lc \quad \ldots\ldots(3).$$

Let the inclination of OP to the axes Ox, Oy, Oz be denoted by λ, μ, ν, respectively.

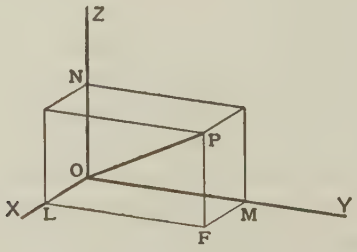

Fig. 1.

Since the sum of the orthogonal projections of the three edges OL, LF and FP on OP must be equal to OP, we have—

$$OP = OL\cos\lambda + LF\cos\mu + FP\cos\nu$$
$$= ha\cos\lambda + kb\cos\mu + lc\cos\nu \ldots\ldots (4).$$

Again, taking the orthogonal projections of OP and of the above three edges of the parallelepiped on each of the axial rays in turn, we obtain the following equations :—

$$\left.\begin{aligned} OP\cos\lambda &= OL + LF\cos\gamma + FP\cos\beta = ha + kb\cos\gamma + lc\cos\beta \\ OP\cos\mu &= ha\cos\gamma + kb + lc\cos\alpha \\ OP\cos\nu &= ha\cos\beta + kb\cos\alpha + lc \end{aligned}\right\} \ldots (5).$$

Multiply both sides of (4) by OP and introduce the values of $OP\cos\lambda$, &c., from (5). We then have—

$$OP^2 = ha(ha + kb\cos\gamma + lc\cos\beta) + kb(ha\cos\gamma + kb + lc\cos\alpha)$$
$$+ lc(ha\cos\beta + kb\cos\alpha + lc) = \Sigma h^2a^2 + 2\Sigma klbc\cos\alpha \ldots\ldots\ldots (6).$$

Prop. 2. To find the direction-cosines of any ray, and the relation which exists between them and the angles between the axial rays.

The direction-cosines are found by introducing in (5) the value of OP given in (6). They are, therefore,—

$$\left.\begin{aligned} \cos\lambda &= \frac{ha + kb\cos\gamma + lc\cos\beta}{\sqrt{\Sigma h^2a^2 + 2\,\Sigma klbc\cos\alpha}} \\ \cos\mu &= \frac{ha\cos\gamma + kb + lc\cos\alpha}{\sqrt{\Sigma h^2a^2 + 2\,\Sigma klbc\cos\alpha}} \\ \cos\nu &= \frac{ha\cos\beta + kb\cos\alpha + lc}{\sqrt{\Sigma h^2a^2 + 2\,\Sigma klbc\cos\alpha}} \end{aligned}\right\} \ldots\ldots (7).$$

Equations (4) and (5) hold for any ray. Eliminating, therefore, OP, ha, kb, lc from the four equations, we obtain the relation which holds between the direction-cosines : it is—

$$\Delta_1 = \begin{vmatrix} 1 & \cos\lambda & \cos\mu & \cos\nu \\ \cos\lambda & 1 & \cos\gamma & \cos\beta \\ \cos\mu & \cos\gamma & 1 & \cos\alpha \\ \cos\nu & \cos\beta & \cos\alpha & 1 \end{vmatrix} = 0 \ldots (8).$$

Prop. 3. To find expressions for the indices of any ray in terms of the angles which it makes with the axial rays.

Solving equations (5) for ha, kb, lc, we have—

$$ha \div \begin{vmatrix} \cos\lambda & \cos\gamma & \cos\beta \\ \cos\mu & 1 & \cos\alpha \\ \cos\nu & \cos\alpha & 1 \end{vmatrix} = kb \div \begin{vmatrix} 1 & \cos\lambda & \cos\beta \\ \cos\gamma & \cos\mu & \cos\alpha \\ \cos\beta & \cos\nu & 1 \end{vmatrix}$$
$$= lc \div \begin{vmatrix} 1 & \cos\beta & \cos\lambda \\ \cos\gamma & 1 & \cos\mu \\ \cos\beta & \cos\alpha & \cos\nu \end{vmatrix} = OP \div \begin{vmatrix} 1 & \cos\gamma & \cos\beta \\ \cos\gamma & 1 & \cos\alpha \\ \cos\beta & \cos\alpha & 1 \end{vmatrix} \ldots (9).$$

Again, if the value of OP given in (4) be introduced into the equations (5), we obtain the following equations, which may be sometimes useful:

$$\left.\begin{aligned} ha\sin^2\lambda+kb(\cos\gamma-\cos\lambda\cos\mu)+lc(\cos\beta-\cos\lambda\cos\mu)&=0\\ ha(\cos\gamma-\cos\lambda\cos\mu)+kb\sin^2\mu+lc(\cos\alpha-\cos\mu\cos\nu)&=0\\ ha(\cos\beta-\cos\lambda\cos\nu)+kb(\cos\alpha-\cos\mu\cos\nu)+lc\sin^2\nu&=0 \end{aligned}\right\}\ldots(10).$$

Prop. 4. To find the equation of the plane perpendicular to a ray (hkl), *i.e.* of the face (hkl).

Suppose the plane to pass through the point P, which is the extremity of the diagonal of the parallelepiped having for edges ha, kb, lc; and let the ray make the angles λ, μ, ν with the axial rays.

The sum of the orthogonal projection on OP of the coordinates x, y, z of any point which lies in the plane is equal to OP.

$$\therefore OP=x\cos\lambda+y\cos\mu+z\cos\nu.$$

Introducing the values of $\cos\lambda$, $\cos\mu$, $\cos\nu$ from (5) and the value of OP^2 from (6), we have—

$$(x-ha)\,(ha+kb\cos\lambda+lc\cos\beta)+(y-kb)\,(ha\cos\gamma+kb+lc\cos\alpha)+(z-lc)\,(ha\cos\beta+kb\cos\alpha+lc)=0\ \ldots\ldots\ (11).$$

The parallel plane through the origin is—

$$x(ha+kb\cos\gamma+lc\cos\beta)+y(ha\cos\gamma+kb+lc\cos\alpha)+z(ha\cos\beta+kb\cos\alpha+lc)=0\ldots\ldots\ldots(12).$$

Prop. 5. To find the angle ϕ between any two rays (hkl) and $(h_1k_1l_1)$.

Let OP in Fig. 1 be the ray (hkl), and let its inclination to the axial rays be λ, μ, ν. Then the relations established in the preceding propositions hold for it. Suppose the ray $(h_1k_1l_1)$ to be given by the diagonal OP_1 of a similar parallelepiped, and its direction-angles to be λ_1, μ_1, ν_1. Then the orthogonal projection of OP on OP_1 must be equal to the sum of the projections of the edges OL, LF, FP on OP_1.

$$\text{Hence, } OP\cos\phi=OL\cos\lambda_1+LF\cos\mu_1+FP\cos\nu_1=ha\cos\lambda_1+kb\cos\mu_1+lc\cos\nu_1\ldots\ldots(13).$$

But $\cos\lambda_1$, $\cos\mu_1$, $\cos\nu_1$, OP_1 are connected together by equations similar to those given in (5). Multiplying both sides of (13) by OP_1, and replacing $OP_1\cos\lambda_1$, &c., by their equivalents, we have—

$$OP.OP_1\cos\phi=ha(h_1a+k_1b\cos\gamma+l_1c\cos\beta)+kb(h_1a\cos\gamma+k_1b+l_1c\cos\alpha)+lc(h_1a\cos\beta+k_1b\cos\alpha+l_1c).$$

Hence—

$$\cos\phi=\frac{\Sigma hh_1a^2+\Sigma bc(kl_1+lk_1)\cos\alpha}{\sqrt{\Sigma h^2a^2+2\Sigma klbc\cos\alpha}\ \sqrt{\Sigma h_1{}^2a^2+2\Sigma k_1l_1bc\cos\alpha}}\ldots\ldots(14).$$

This expression is simpler and more easily computed than either of the expressions (44) and (47) of pages 569 and 570 of my *Treatise on Crystallography*. It can also be easily transformed into either of them by the relations (2). Thus to get (47) we need only substitute for a, b, c from (2), when we have—

$$\text{Cos } \phi = \frac{\Sigma \frac{hh_1}{a^2} \sin^2\alpha + \Sigma \frac{kl_1 + lk_1}{bc} \sin\beta \sin\gamma \cos\alpha}{\sqrt{\Sigma \frac{h^2}{a^2} \sin^2\alpha + 2\Sigma \frac{kl}{bc} \sin\beta \sin\gamma \cos\alpha} \sqrt{\Sigma \frac{h_1^2}{a^2} \sin^2\alpha + 2\Sigma \frac{k_1 l_1}{bc} \sin\beta \sin\gamma \cos\alpha}}$$

Equation (44) is found by a similar substitution from (2*), and the relations of a spherical triangle—

$$\text{Cos}\alpha = \cos\beta \cos\gamma + \sin\beta \sin\gamma \cos(A = \pi - \alpha_1), \text{ \&c.}$$

We shall now show how this method can be applied to the solution of crystallographic problems. Thus let us take an anorthic crystal, and let it be required to find the linear elements from a knowledge of some of the angles. Adopting the letters and notation of page 161 of my *Treatise*, let us suppose the zone $[BLC] = [010, 001]$ to be known. Introducing the indices 0,1,1 of L into the first and second equations of (7), we have—

$$\cos(AL = 100 \wedge 011) = \frac{b \cos\gamma + c \cos\beta}{\sqrt{b^2 + c^2 + 2bc \cos\alpha}} \quad \ldots\ldots (15)$$

$$\text{and } \sec^2(D = 010 \wedge 011) = \frac{b^2 + c^2 + 2bc \cos\alpha}{(b + c \cos\alpha)^2};$$

$$\therefore \tan^2 D = \sec^2 D - 1 = \frac{c^2(1 - \cos^2\alpha)}{(b + c \cos\alpha)^2};$$

$$\therefore \tan D = \frac{c \sin\alpha}{b + c \cos\alpha} \quad \ldots\ldots\ldots (16)$$

$$\text{Also } \frac{\sin D}{c \sin\alpha} = \frac{\cos D}{b + c \cos\alpha} = \frac{\sin(\alpha - D)}{b \sin\alpha};$$

$$\therefore \frac{b}{c} = \frac{\sin(\alpha - D)}{\sin D} = \frac{\sin D_1}{\sin D} \quad \ldots\ldots\ldots (17)$$

This equation, which gives the parametral ratio $\frac{b}{c}$, is given by Grassmann, p. 138; but as he endeavours to connect the ratio with the distances between consecutive particles, his expression differs slightly from

the above. It can, by means of the relations (2), be easily transformed into the equations giving the parameters on the corresponding zone-axes. This latter expression is—

$$\frac{c}{b}\frac{\sin\beta}{\sin\gamma}=\frac{\sin D_1}{\sin D};$$

$$\text{Or}\quad \frac{b}{c}=\frac{\sin BL}{\sin CL}\cdot\frac{\sin CA}{\sin AB}\ldots\ldots\ldots(18).$$

By introducing into (7) the values (101) and (110), we get corresponding expressions for the other parametral ratios. They are—

$$\frac{c}{a}=\frac{\sin E_1}{\sin E},\quad\text{and}\quad\frac{a}{b}=\frac{\sin F_1}{\sin F}\ldots\ldots\ldots(19).$$

Again, if L is $0kl$, we have from the second equation of (7)—

$$\cos BL_1=\frac{kb+lc\cos\alpha}{\sqrt{k^2b^2+l^2c^2+2kl\,bc\cos\alpha}},$$

$$\text{whence}\quad\tan BL_1=\frac{lc\sin\alpha}{kb+lc\cos\alpha}\ldots\ldots\ldots(20).$$

$$\text{and}\quad\frac{\sin BL_1}{\sin(\alpha-BL_1)}=\frac{\sin BL_1}{\sin CL_1}=\frac{lc}{kb}\ldots\ldots\ldots(21)$$

Dividing (21) by (17), we have the anharmonic ratio of the four poles $\{BL_1LC\}$, which is—

$$\frac{\sin BL_1}{\sin CL_1}\div\frac{\sin BL}{\sin CL}=\frac{l}{k}\ldots\ldots\ldots(22).$$

The deduction of special formulæ for the systems of greater symmetry is easy. We shall at present limit ourselves to the consideration of the rhombohedral system.

Rhombohedral system.

In this system the normals to the fundamental trigonal pyramid or rhombohedron are selected as the axial rays, and the triad axis as the parametral ray (111).

Hence $\alpha=\beta=\gamma$; and $a=b=c=1$(say).

Equations (5) become—

$$\left.\begin{aligned}OP\cos\lambda&=h+(k+l)\cos\alpha=h(1-\cos\alpha)+\theta\cos\alpha\\ OP\cos\mu&=k(1-\cos\alpha)+\theta\cos\alpha\\ OP\cos\nu&=l(1-\cos\alpha)+\theta\cos\alpha\end{aligned}\right\}\ldots\ldots(23);$$

Where $\theta=h+k+l$.

Also, $OP^2=\Sigma h^2+2\cos\alpha\,\Sigma kl=\theta^2\cos\alpha+(1-\cos\alpha)\Sigma h^2$.....(24).

And,

$$\left.\begin{aligned}\cos\lambda&=\frac{h(1-\cos\alpha)+\theta\cos\alpha}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}}\\ \cos\mu&=\frac{k(1-\cos\alpha)+\theta\cos\alpha}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}}\\ \cos\nu&=\frac{l(1-\cos\alpha)+\theta\cos\alpha}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}}\end{aligned}\right\}\ .....(25).$$

Δ_1 becomes—

$$(1-\cos\alpha)^2(1+2\cos\alpha)-(1-\cos^2\alpha)\,\Sigma\cos^2\lambda +2\cos\alpha(1-\cos\alpha)\Sigma\cos\lambda\cos\mu.$$

Since this is equal to zero, we obtain as the relation between the direction-cosines—

$$(1+\cos\alpha)\Sigma\cos^2\lambda-2\cos\alpha\,\Sigma\cos\lambda\cos\mu=(1-\cos\alpha)(1+2\cos\alpha).....(26).$$

When the ray coincides with the triad axis, $\lambda=\mu=\nu=D=111\wedge100$. Equation (26) then reduces to—

$$3(1-\cos\alpha)\cos^2D=(1-\cos\alpha)(1+2\cos\alpha);$$
$$\therefore\ 3\cos^2D=1+2\cos\alpha.....(27).$$

Hence—
$$2\cos\alpha=\frac{2-\tan^2D}{1+\tan^2D}.....(28).$$

Again,
$$3\sin^2D=2(1-\cos\alpha)=4\sin^2\frac{\alpha}{2}.....(29).$$

This last equation is equivalent to the well-known formula—

$$\sin r'r/2=\sin 60^\circ\sin D;$$

Where r and r' are two poles of the fundamental rhombohedron.

The expression (14) for the cosine of the angle between the rays (hkl) and $(h_1k_1l_1)$ becomes—

$$\cos\phi=\frac{\Sigma hh_1+\cos\alpha\Sigma(kl_1+k_1l)}{\sqrt{\Sigma h^2+2\cos\alpha\,\Sigma kl}\quad\sqrt{\Sigma h_1{}^2+2\cos\alpha\,\Sigma k_1l_1}}.....(30).$$

If $\cos\alpha$ is replaced by its equivalent given in (28), we obtain the following expressions for the cosine:—

$$\cos\phi=\frac{2\{\Sigma hh_1+\Sigma(kl_1+k_1l)\}+\tan^2D\{2\Sigma hh_1-\Sigma(kl_1+k_1l)\}}{\sqrt{2(\Sigma h^2+2\Sigma kl)+2\tan^2D(\Sigma h^2-\Sigma kl)}\quad\sqrt{2(\Sigma h_1{}^2+2\Sigma k_1l_1)+2\tan^2D(\Sigma h_1{}^2-\Sigma k_1l_1)}}$$
$$=\frac{2\theta\theta_1+\tan^2D\Sigma(k-l)(k_1-l_1)}{\sqrt{2\theta^2+\tan^2D\Sigma(k-l)^2}\quad\sqrt{2\theta_1{}^2+\tan^2D\Sigma(k_1-l_1)^2}}.....(31);$$

where $\theta_1=h_1+k_1+l_1$.

By means of the equations above given, and the relations of the spherical triangles formed by P with the axial poles and with the poles C, N, m, m', m'', a', &c., marked in Fig. 2, we can easily establish the relations in general use for the solution of problems respecting rhombohedral crystals.

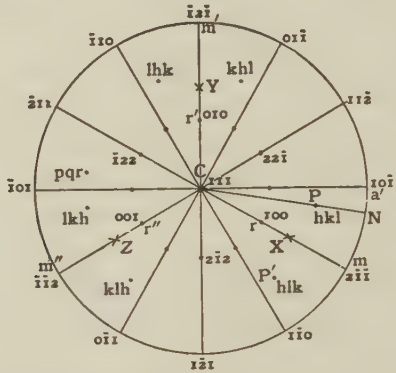

Fig. 2.

Or employing the general equations (30) and (31), and C being (111), we have—

$$\cos CP = \frac{\theta\sqrt{(1+2\cos\alpha)}}{\sqrt{3\{\Sigma h^2 + 2\cos\alpha\Sigma kl\}}}$$

$$= \frac{\theta\sqrt{2}}{\sqrt{2\theta^2 + \tan^2 D\Sigma(k-l)^2}} \ldots\ldots\ldots(32).$$

By transforming the first equivalent, we have—

$$\tan CP = \frac{\sqrt{(1-\cos\alpha)\Sigma(k-l)^2}}{\theta\sqrt{(1+2\cos\alpha)}} \ldots\ldots\ldots(33).$$

By transforming the second equivalent, we obtain—

$$\tan CP = \frac{\sqrt{\Sigma(k-l)^2}}{\theta\sqrt{2}} \tan D \ldots\ldots\ldots(34);$$

and this can be shown to be the result of replacing $\cos\alpha$ in (33) by its equivalent in terms of $\tan D$.

Again, taking 2ξ, 2η to be the angles, respectively, over the obtuse and acute polar edges of a scalenohedron $\{hkl\}$, and 2ζ to be that over each of its median edges, we have—

$$\cos 2\xi = \cos hkl \wedge hlk = \frac{h^2+2kl+\cos\alpha\{\theta^2-(h^2+2kl)\}}{\Sigma h^2 + 2\cos\alpha\Sigma kl}$$

$$= \frac{2\theta^2+\tan^2 D\{3(h^2+2kl)-\theta^2\}}{2\theta^2+\tan^2 D\Sigma(k-l)^2} \ldots\ldots\ldots(35).$$

$$\text{Hence } 2\sin^2\xi = \frac{2(k-l)^2\sin^2\frac{\alpha}{2}}{\Sigma h^2+2\cos\alpha\,\Sigma kl} = \frac{3(k-l)^2\tan^2 D}{2\theta^2+\tan^2 D\,\Sigma(k-l)^2} \quad \ldots\ldots(36).$$

Similarly,

$$\cos 2\eta = \cos(hkl\wedge khl) = \frac{l^2+2hk+\cos\alpha\{\theta^2-(l^2+2hk)\}}{\Sigma h^2+2\cos\alpha\,\Sigma kl}$$

$$= \frac{2\theta^2+\tan^2 D\{3(l^2+2hk)-\theta^2\}}{2\theta^2+\tan^2 D\,\Sigma(k-l)^2} \quad \ldots\ldots(37).$$

$$\therefore\ 2\sin^2\eta = \frac{2(h-k)^2\sin^2\frac{\alpha}{2}}{\Sigma h^2+2\cos\alpha\,\Sigma kl} = \frac{3(h-k)^2\tan^2 D}{2\theta^2+\tan^2 D\,\Sigma(k-l)^2} \quad \ldots\ldots(38).$$

And—

$$\cos 2\zeta = \cos hkl\wedge\bar{l}\,\bar{k}\bar{h} = \frac{-(k^2+2hl)-\cos\alpha\{\theta^2-(k^2+2hl)\}}{\Sigma h^2+2\cos\alpha\,\Sigma\,kl}$$

$$= \frac{-2\theta^2-\tan^2 D\{3(k^2+2hl)-\theta^2\}}{2\theta^2+\tan^2 D\,\Sigma(k-l)^2} \quad \ldots\ldots(39).$$

Hence

$$2\cos^2\zeta = \frac{2(h-l)^2\sin^2\frac{\alpha}{2}}{\Sigma h^2+2\cos\alpha\,\Sigma kl} = \frac{3(h-l)^2\tan^2 D}{2\theta^2+\tan^2 D\,\Sigma(k-l)} \quad \ldots\ldots(40).$$

Now each of the angles ξ, η, ζ is less than 90°, for the angles over the scalenohedral edges are each less than 180°. Therefore taking, as we are at liberty to do, h, k and l to be in descending order of magnitude, and their sum to be greater than unity, the positive values must be taken when the square roots of equations (36), (38) and (40) are extracted. We have, therefore,—

$$\left.\begin{aligned}
\sin\xi &= \frac{(k-l)\sin\frac{\alpha}{2}}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}} = \frac{(k-l)\sqrt{3}\tan D}{\sqrt{4\theta^2+2\tan^2 D\Sigma(k-l)^2}};\\
\sin\eta &= \frac{(h-k)\sin\frac{\alpha}{2}}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}} = \frac{(h-k)\sqrt{3}\tan D}{\sqrt{4\theta^2+2\tan^2 D\Sigma(k-l)^2}};\\
\cos\zeta &= \frac{(h-l)\sin\frac{\alpha}{2}}{\sqrt{\Sigma h^2+2\cos\alpha\Sigma kl}} = \frac{(h-l)\sqrt{3}\tan D}{\sqrt{4\theta^2+2\tan^2 D\Sigma(k-l)^2}}
\end{aligned}\right\} \quad \ldots\ldots(41).$$

Hence,

$$\frac{\sin\xi}{k-l}=\frac{\sin\eta}{h-k}=\frac{\cos\zeta}{h-l}=\frac{\sin\frac{a}{2}}{\sqrt{\Sigma h^2+2\cos a\Sigma kl}}$$

$$=(\text{by transformation from (32)})\ \frac{\sqrt{3}\sin CP}{\sqrt{2\Sigma(k-l)^2}}=\frac{\sqrt{3}\tan D}{\sqrt{4\theta^2+2\tan^2 D\,\Sigma(k-l)^2}}$$

$$=(\text{from (32)})\ \frac{\sqrt{3}\tan D\cos CP}{2\theta}\ldots\ldots(42);$$

$$\text{and } \sin\xi+\sin\eta=\cos\zeta\ldots\ldots(43).$$

On the determination of the positions of points and planes after rotation through a definite angle about a known axis.

By R. W. H. T. Hudson, B.A,
Communicated by Prof. W. J. Lewis, M.A.

[Read April 3rd, 1900.]

I.

Rectangular axes.

TAKE three axes of reference OX, OY, OZ mutually at right angles. A convention must be made as to the positive direction of rotation about any line, and that usually adopted is as follows. A positive rotation about OX rotates OY towards OZ, one about OY rotates OZ towards OX, and one about OZ rotates OX towards OY. To find the positive direction of rotation for any line ON we must suppose ON moved to coincide with one of the axes, say OZ, and then apply the preceding rule.

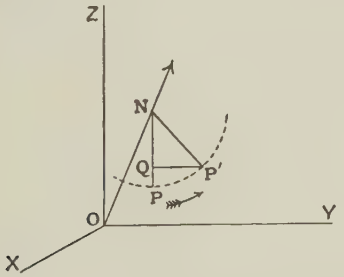

Fig. 1.

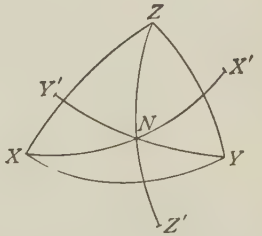

Fig. 2.

Taking the axes as indicated in the figure, in which OX is supposed drawn towards the observer, a positive rotation about any line ON together with a translation along ON produces right handed screwing. If the axes OX and OY were interchanged, the screwing would be left-handed.

The figure represents the displacement of a point P to the position P' by rotation through an angle ϕ about ON in the positive direction. The problem is to determine the co-ordinates $(x'y'z')$ of P' in terms of those of $P(xyz)$, ϕ and the given direction ON.

Let $\angle NOX = \lambda$, $\angle NOY = \mu$, $\angle NOZ = \nu$.

PN, $P'N$ are perpendicular to ON and $\angle PNP' = \phi$.

$P'Q$ is perpendicular to NP.

To find ON we notice that it is the projection of OP on ON. Hence

$$ON = OP \cos PON = OP\left\{\frac{x}{OP}\cos\lambda + \frac{y}{OP}\cos\mu + \frac{z}{OP}\cos\nu\right\}$$
$$= x\cos\lambda + y\cos\mu + z\cos\nu \quad \ldots\ldots\ldots\ldots\ldots (1)$$

It is convenient to use the co-ordinates of N which are $\xi\eta\zeta$ where

$$\xi = ON\cos\lambda = (x\cos\lambda + y\cos\mu + z\cos\nu)\cos\lambda$$
$$\eta = ON\cos\mu = (x\cos\lambda + y\cos\mu + z\cos\nu)\cos\mu$$
$$\zeta = ON\cos\nu = (x\cos\lambda + y\cos\mu + z\cos\nu)\cos\nu$$

The direction of QP' is required.

The direction-cosines of ON are $\cos\lambda$, $\cos\mu$, $\cos\nu$.

$$\text{,,} \qquad NP \text{ ,, } \frac{x-\xi}{NP}, \frac{y-\eta}{NP}, \frac{z-\zeta}{NP}$$
$$\text{or say} \quad p \quad , \quad q \quad , \quad r \ .$$

Hence those of QP', which is perpendicular to both, are

$$\pm(r\cos\mu - q\cos\nu), \pm(p\cos\nu - r\cos\lambda), \pm(q\cos\lambda - p\cos\mu).$$

The ambiguous sign is determined by the fact that, if ON be moved to coincide with OZ and NP to the direction OX, QP' will then be in the direction OY. That is, when $\cos\lambda = 0 = \cos\mu$, $\cos\nu = 1$, $p = 1$, $q = 0 = r$, we must have

$$\pm(p\cos\nu - r\cos\lambda) = 1.$$

Hence the upper sign must be taken.

We are now in a position to write down the co-ordinates of P', because we know the lengths and directions of ON, NQ, QP'.

Thus
$$x' = ON\cos\lambda + NQ.p + QP'(r\cos\mu - q\cos\nu)$$
$$= \xi + NP'\cos\phi.\frac{x-\xi}{NP} + NP'\sin\phi\,(r\cos\mu - q\cos\nu)$$
$$= \xi + \cos\phi\,(x-\xi) + \sin\phi\,(z\cos\mu - y\cos\nu)$$

Or
$$x' - x = (1-\cos\phi)(\xi - x) + \sin\phi\,(z\cos\mu - y\cos\nu)$$
Similarly,
$$y' - y = (1-\cos\phi)(\eta - y) + \sin\phi\,(x\cos\nu - z\cos\lambda)$$
and
$$z' - z = (1-\cos\phi)(\zeta - z) + \sin\phi\,(y\cos\lambda - x\cos\mu)$$
$\ldots\ldots (2)$;

wherein ξ, η, ζ have the values found above.

The relations (2), which give the new position of any point, are established in Minchin's *Statics*, II, p. 103, 1889; and his method of proof is that followed above.

If $x\ y\ z$ are required in terms of $x'y'z'$, it is necessary only to interchange x and x', &c. in the above formulæ and to change the sign of ϕ.

Suppose that it is required to find the new position of a plane

$$hx/a+ky/b+lz/c=1.$$

Now the point h/a, k/b, l/c is the pole P of this plane with respect to the sphere

$$x^2+y^2+z^2=1;$$

and the relation of pole and polar is unchanged by any rotation about 0. Hence the new position of the plane is

$$h'x/a+k'y/b+l'x/c=1;$$

where h'/a, k'/b, l'/c are the co-ordinates of the new position P' of the original pole P. They are therefore obtained from (2), and are

$$\left.\begin{aligned}
\frac{h'}{a} &= \frac{h}{a}\cos\phi+ON\cos\lambda\,(1-\cos\phi)+\sin\phi\left(\frac{l}{c}\cos\mu-\frac{k}{b}\cos\nu\right)\\
\frac{k'}{b} &= \frac{k}{b}\cos\phi+ON\cos\mu\,(1-\cos\phi)+\sin\phi\left(\frac{h}{a}\cos\nu-\frac{l}{c}\cos\lambda\right)\\
\frac{l'}{c} &= \frac{l}{c}\cos\phi+ON\cos\nu\,(1-\cos\phi)+\sin\phi\left(\frac{k}{b}\cos\lambda-\frac{h}{a}\cos\mu\right)
\end{aligned}\right\}\ldots\ldots(3),$$

where $ON=\dfrac{h}{a}\cos\lambda+\dfrac{k}{b}\cos\mu+\dfrac{l}{c}\cos\nu.$

II. *Oblique axes.*

Choose rectangular axes as in case I, and let the oblique axes, referred to them, have direction cosines $(l_1m_1n_1)$, $(l_2m_2n_2)$, $(l_3m_3n_3)$.

Let OP make angles $\theta_1\,\theta_2\,\theta_3$ with the oblique axes.

Then $\cos\theta_i=(l_ix+m_iy+n_iz)\div OP$, $(i=1, 2, 3)$.

It is required to find the angles $\theta_1'\,\theta_2'\,\theta_3'$ made by OP' with the oblique axes.

We have $\cos\theta_i'=(l_ix'+m_iy'+n_iz')\div OP'$, $(i=1, 2, 3)$.

Hence, multiplying the formulæ (2) respectively by $\dfrac{l}{OP}$, $\dfrac{m}{OP}$, $\dfrac{n}{OP}$ (dropping the suffix) and adding, we obtain

$$\cos\theta'=\cos\phi\cos\theta+(1-\cos\phi)\frac{l\xi+m\eta+n\zeta}{OP}+\sin\phi\begin{vmatrix} l & m & n\\ \cos\lambda & \cos\mu & \cos\nu\\ \dfrac{x}{OP} & \dfrac{y}{OP} & \dfrac{z}{OP}\end{vmatrix}$$

Now, if the axis of rotation ON makes angles $\omega_1\ \omega_2\ \omega_3$ with the oblique axes, then

$$\cos\omega_i = l_i\frac{\xi}{ON} + m_i\frac{\eta}{ON} + n_i\frac{\zeta}{ON}, (i=1, 2, 3).$$

$\therefore \cos\theta_i' = \cos\phi\cos\theta_i + (1-\cos\phi).\cos PON.\cos\omega_i + \sin\phi\,\Delta_i$.....(4).

where

$$\Delta_i^2 =$$

$$\begin{vmatrix} l_i^2+m_i^2+n_i^2, & l_i\cos\lambda+m_i\cos\mu+n_i\cos\nu, & l_i\frac{x}{OP}+m_i\frac{y}{OP}+n_i\frac{z}{OP} \\ l_i\cos\lambda+m_i\cos\mu+n_i\cos\nu, & \cos^2\lambda+\cos^2\mu+\cos^2\nu, & \cos\lambda\frac{x}{OP}+\cos\mu\frac{y}{OP}+\cos\nu\frac{z}{OP} \\ l_i\frac{x}{OP}+m_i\frac{y}{OP}+n_i\frac{z}{OP}, & \cos\lambda\frac{x}{OP}+\cos\mu\frac{y}{OP}+\cos\nu\frac{z}{OP}, & \frac{x^2+y^2+z^2}{O^2P} \end{vmatrix}$$

$$= \begin{vmatrix} 1 & \cos\omega_i & \cos\theta_i \\ \cos\omega_i & 1 & \cos PON \\ \cos\theta_i & \cos PON & 1 \end{vmatrix} \quad \text{.....(5).}$$

It remains only to calculate $\cos PON$ in terms of $\omega_1\ \omega_2\ \omega_3$, $\theta_1\ \theta_2\ \theta_3$, and the angles α, β, γ between the oblique axes.

Let e, f, g be the direction ratios of OP.

Construct a parallelepiped, having OP as diagonal, and edges parallel to the oblique axes, and project on ON, we then obtain

$$\cos PON = e\cos\omega_1 + f\cos\omega_2 + g\cos\omega_3.$$

Again, projecting on the oblique axes, we get—

$$\cos\theta_1 = e + f\cos\gamma + g\cos\beta$$
$$\cos\theta_2 = e\cos\gamma + f + g\cos\alpha$$
$$\cos\theta_3 = e\cos\beta + f\cos\alpha + g$$

Eliminate e, f, g.

$$\therefore \begin{vmatrix} \cos PON & \cos\omega_1 & \cos\omega_2 & \cos\omega_3 \\ \cos\theta_1 & 1 & \cos\gamma & \cos\beta \\ \cos\theta_2 & \cos\gamma & 1 & \cos\alpha \\ \cos\theta_3 & \cos\beta & \cos\alpha & 1 \end{vmatrix} = 0$$

Or $\cos PON \begin{vmatrix} 1 & \cos\gamma & \cos\beta \\ \cos\gamma & 1 & \cos\alpha \\ \cos\beta & \cos\alpha & 1 \end{vmatrix} + \begin{vmatrix} 1 & \cos\gamma & \cos\beta & \cos\theta_1 \\ \cos\gamma & 1 & \cos\alpha & \cos\theta_2 \\ \cos\beta & \cos\alpha & 1 & \cos\theta_3 \\ \cos\omega_1 & \cos\omega_2 & \cos\omega_3 & 0 \end{vmatrix} = 0$ .....(6)

Thus $\cos I\,ON$ is found, and thence Δ_1, Δ_2, Δ_3, and the result may be stated as follows:

If the line OP, making angles $\theta_1\ \theta_2\ \theta_3$ with the axes, is turned through an angle ϕ about ON, making angles $\omega_1\ \omega_2\ \omega_3$ with the axes, into the position OP' having the direction-angles $\theta_1'\ \theta_2'\ \theta_3'$, then

$$\cos\theta_i' = \cos\phi\cos\theta_i + (1-\cos\phi)\cos PON\cos\omega_i + \sin\phi\,\Delta_i, (i=1,2,3).$$

To find the new position of any plane we notice that the direction cosines of the normal to the plane $h\frac{x}{a}+k\frac{y}{b}+l\frac{z}{c}=1$ are $\rho\frac{h}{a}$, $\rho\frac{k}{b}$, $\rho\frac{l}{c}$, where ρ is the perpendicular from O on the plane, and is unaltered by the rotation.

Thus the formulæ required are:

$$\left.\begin{aligned}\frac{h'}{a} &= \frac{h}{a}\cos\phi + (1-\cos\phi)\frac{\cos PON}{\rho}\cos\omega_1 + \sin\phi\,D_1\\ \frac{k'}{b} &= \frac{k}{b}\cos\phi + (1-\cos\phi)\frac{\cos PON}{\rho}\cos\omega_2 + \sin\phi\,D_2\\ \frac{l'}{c} &= \frac{l}{c}\cos\phi + (1-\cos\phi)\frac{\cos PON}{\rho}\cos\omega_3 + \sin\phi\,D_3\end{aligned}\right\}\ldots\ldots(7)$$

where

$$-\frac{\cos PON}{\rho} = \begin{vmatrix} 1 & \cos\gamma & \cos\beta & h/a\\ \cos\gamma & 1 & \cos\alpha & k/b\\ \cos\beta & \cos\alpha & 1 & l/c\\ \cos\omega_1 & \cos\omega_2 & \cos\omega_3 & 0\end{vmatrix} \div \begin{vmatrix} 1 & \cos\gamma & \cos\beta\\ \cos\gamma & 1 & \cos\alpha\\ \cos\beta & \cos\alpha & 1\end{vmatrix} \cdot ;\ldots\ldots(8)$$

$$D_1^2 = \begin{vmatrix} 1 & \cos\omega_1 & h/a\\ \cos\omega_1 & 1 & \rho^{-1}\cos PON\\ h/a & \rho^{-1}\cos PON & \rho^{-2}\end{vmatrix};\ \&c.;\ \ldots\ldots(9)$$

and ρ is given by

$$\begin{vmatrix} 1 & \cos\gamma & \cos\beta & h/a\\ \cos\gamma & 1 & \cos\alpha & k/b\\ \cos\beta & \cos\alpha & 1 & l/c\\ h/a & k/b & l/c & \rho^{-2}\end{vmatrix} = 0\ldots\ldots\ldots\ldots(10)$$

When the angle of rotation is 180° the formulæ of transformation can be obtained directly as follows:

Let as before the plane $hx/a+ky/b+lz/c=1$ become

$$h'x/a+k'y/b+l'z/c=1.$$

The relative motion of the plane and axes is the same as if the plane were fixed and the axes were turned through 180° about ON. Let the

axes meet a sphere with radius ON in X, Y, Z, Fig. 2, p. 343; and let their positions after a semi-revolution about ON be given by X', Y', Z'.

Then $$X'N=NX;\ Y'N=NY;\ Z'N=NZ.$$

And

$$\left.\begin{aligned}&\text{Cos } X'X=\cos 2\,XN=2\cos^2 XN-1=2\cos^2\omega_1-1.\\&\text{Cos } X'Y+\cos XY=2\cos XN\cos YN;\ \therefore\cos X'Y=2\cos\omega_1\cos\omega_2-\cos\gamma.\\&\text{Cos } X'Z+\cos XZ=2\cos XN\cos ZN;\ \therefore\cos X'Z=2\cos\omega_1\cos\omega_3-\cos\beta.\end{aligned}\right\}\ldots(11)$$

But $x\ y\ z$ being the point at distance r on OX' at which the plane is met, then

$$\left.\begin{aligned}r\cos XX'&=x+y\cos\gamma+z\cos\beta,\\r\cos YX'&=x\cos\gamma+y+z\cos\alpha,\\r\cos ZX'&=x\cos\beta+y\cos\alpha+z.\\1&=hx/a+ky/b+lz/c\end{aligned}\right\}\ldots\ldots(12)$$

Eliminating x, y and z, and replacing cos XX', &c. by their values given in (11), and r by its equivalent $a\div h'$, we have—

$$\begin{vmatrix}2\cos^2\omega_1-1 & 1 & \cos\gamma & \cos\beta\\ 2\cos\omega_1\cos\omega_2-\cos\gamma & \cos\gamma & 1 & \cos\alpha\\ 2\cos\omega_1\cos\omega_3-\cos\beta & \cos\beta & \cos\alpha & 1\\ \dfrac{(h'+h)-h}{a}, & \dfrac{h}{a} & \dfrac{k}{b} & \dfrac{l}{c}\end{vmatrix}=0.$$

This reduces to

$$\begin{vmatrix}\cos\omega_1 & 1 & \cos\gamma & \cos\beta\\ \cos\omega_2 & \cos\gamma & 1 & \cos\alpha\\ \cos\omega_3 & \cos\beta & \cos\alpha & 1\\ \dfrac{h_1+h}{2a\cos\omega_1} & \dfrac{h}{a} & \dfrac{k}{b} & \dfrac{l}{c}\end{vmatrix}=0\ldots\ldots(13\ ;$$

which may be expressed by

$$(h_1+h)D-2a\cos\omega_1\Delta=0.$$

The formulæ of transformation are therefore

$$\frac{h'+h}{a\cos\omega_1}=\frac{k'+k}{b\cos\omega_2}=\frac{l'+l}{c\cos\omega_3}=\frac{2\Delta}{D}\ldots\ldots(14)\ ;$$

where

$$\Delta=\begin{vmatrix}\cos\omega_1 & 1 & \cos\gamma & \cos\beta\\ \cos\omega_2 & \cos\gamma & 1 & \cos\alpha\\ \cos\omega_3 & \cos\beta & \cos\alpha & 1\\ 0 & \dfrac{h}{a} & \dfrac{k}{b} & \dfrac{l}{c}\end{vmatrix},\ \text{and}\ D=\begin{vmatrix}1 & \cos\gamma & \cos\beta\\ \cos\gamma & 1 & \cos\alpha\\ \cos\beta & \cos\alpha & 1\end{vmatrix}.$$

Communications from the Oxford Mineralogical Laboratory.

1. *On a Rhombic Pyroxene from South Africa.*

2. *On a method of illustrating the variation of thermal conductivity of crystals in different directions.*

3. *A twin crystal of Sapphire.*

4. *On Monazite and associated minerals from Tintagel, Cornwall.*

By H. L. Bowman, M.A., Demonstrator in Mineralogy.

1. *On a Rhombic Pyroxene from South Africa.*

[Read June 20th, 1899.]

THE stones to which this paper refers were sent to Prof. Miers for determination by Mr. Francis Powell, and were stated to come "from the diamond washings." They are of a fine green colour, and quite transparent, and possess a highly perfect cleavage parallel to the faces of a prism having an angle of about 88°. This serves to distinguish the material from olivine, which it otherwise much resembles, and —coupled with the uniformly straight extinction through cleavage flakes, the specific gravity (3·199) and hardness (6—7)—suffices to identify the mineral as one of the rhombic pyroxenes.

Since unaltered rhombic pyroxenes, such as the present, are rare, and but few of the known occurrences have ever been completely examined, it seemed desirable to submit the stones to a thorough examination.

The mineral occurs in small irregular fragments up to 6 or 8 mm. in diameter, devoid of crystal faces, but partly bounded in some cases by cleavage planes, the surface being perfectly fresh. In addition to the very good prismatic cleavage of 88°0′ (mean of 15 measurements), there are two other less perfect cleavages, parallel to $a(100)$ and $b(010)$ respectively. These are visible on some fragments as numerous minute parallel surfaces, which give a good single image of the goniometer signal. They are also brought out in grinding sections perpendicular to the prism. The cleavages are not always easily obtained, and the crystals often show a conchoidal fracture. The prismatic cleavage-angle corresponds to an axial ratio—$a : b = 0{\cdot}9657 : 1$,

The surface of the fragments often has a characteristic drusy appearance due to the cleavage, and one specimen shows a platy structure, as if due to a twin-parting parallel to $b(010)$. This, together with occasional absence of extinction and a fracture recalling the "ripple fracture" of quartz, probably indicates the existence of twin-lamellation. The stones have a fine green colour, sometimes of a rather light shade and inclining to olive, and are quite clear and transparent, closely resembling in appearance some varieties of olivine. The sp. gr. is 3·199, and the hardness between 6 and 7. The lustre is vitreous, and the streak nearly colourless. Several of the cleavage prisms show a fine straight line running transversely across them, the cleavage surfaces on either side of the line not being quite in the same plane. I have measured 3 crystals, and find that the cleavages on the two parts are inclined to one another at a constant angle of about 2°10′, the numbers varying between 2°1′ and 2°16′, and the mean of 6 measurements being 2°9½′. The disposition of the salient and re-entrant angles shows that the (100) faces of both individuals would lie in the same plane, and that the (010) faces would be inclined to one another at an angle of 3°6′. If the combination is to be considered a twin, the indices of the twin-plane would be near to (0.1.21).

In polarised light cleavage flakes show straight extinction, and in convergent sodium light a cleavage prism affords traces of a wide angle — bisectrix at the edge of the field, the plane of the optic axes lying parallel to the trace of the cleavage, and the bisectrix emerging in the equatorial plane. (This bisectrix does not, however, emerge through the horizontal plane, but through the second cleavage at the side of the prism.)

The plane of the optic axes is parallel to $b(010)$, *i.e.* to the shorter diagonal of the cleavage prism, the + acute bisectrix being parallel to the vertical axis $\dot{c}$. Thus, the optical scheme is $\alpha\ \beta\ \gamma = a\ b\ c$.

The birefringence is rather weak.

For the measurement of the optic axial angle two fragments were ground down to plates parallel to $c(001)$ and $a(100)$.[1] The plates were immersed in olive oil, of refractive index 1·4707, and gave the following values for 2H:—

$$2H_a = 88°34' \qquad 2H_o = 135°24' \text{ (Na light)};$$
$$\text{whence } 2V = 74°\ 5' \quad \text{and } \beta = 1{\cdot}705.$$

[1] The perfect prismatic cleavage rendered this a process of some difficulty. I found fine carborundum, used with water on an iron or pewter lap, to be the most convenient grinding material, as flour emery is exceedingly slow in action, and a coarser emery is very apt to break the specimen along the cleavages.

The dispersion about the acute bisectrix is $\rho > v$.

In order to determine the refractive indices I employed a prism, for the preparation of which Mr. Fletcher kindly allowed me to use the Tutton cutting and grinding instrument in the British Museum. The material at my command only sufficed for the preparation of one prism, and this was ground so that its angle is approximately bisected by the plane (100), and its edge is parallel to the vertical axis. The bisecting plane deviates about 1° from the plane (100), but this error will not materially affect the value of the resulting indices. The values of β and γ obtained with this prism are:—

$$\left.\begin{array}{rcl} \beta & = & 1{\cdot}669 \\ \gamma & = & 1{\cdot}675 \end{array}\right\} \text{ (Na light)}^1.$$

The pleochroism is rather weak:—

$\breve{a}$ pale yellow $\quad$ $\bar{b}$ pale green $\quad$ $\dot{c}$ pale yellowish-green

An approximate analysis of some of the material yielded me the following numbers:—

$SiO_2 = 56{\cdot}0$, $FeO = 5{\cdot}0$, $MnO = 0{\cdot}5$, $Al_2O_3 = 2{\cdot}5$, $Cr_2O_3 = 0{\cdot}6$, $MgO = 36{\cdot}5 \ldots . = 101{\cdot}1$

I learn from Mr. Powell that he has received the stones from different sources, the association being with "a darker blackish green stone and fine red garnet." Some are said to be from Griqualand West, where they are found in the diamond washings.

In the Museum of Practical Geology I have found among the exhibits from the Diamond Fields two specimens of washings, from Kimberley Mine and from Du Toit's Pan respectively, which contain green fragments closely resembling the present material in colour and drusy surface-appearance, and it seems not improbable that they may be identical with it, as in specific gravity they fall within the same limits. They are associated with red garnet (which forms the chief constituent of the washings), quartz, and a little iron pyrites.

Green transparent rhombic pyroxenes have been already described from South Africa, namely:—

By Maskelyne and Flight [*Q. J. G. S.* XXX, 406, 1874] from the "blue ground" at Du Toit's Pan, Bultfontein, and Colesberg Kopje—all in the neighbourhood of Kimberley.

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[1] The difference between the values of β as calculated from the axial angle and as measured with the prism, may perhaps be due to a variation in the optical characters of the three specimens used, corresponding to a slight observed difference in the specific gravity. The prism value is probably the most reliable.

By Maskelyne, in a rock from Lydenburg and Korn Kopje, in the Transvaal [*Phil. Mag.* (5) VII, 135, 1879].

By Friedel [*Bull. Soc. Min. d. France*, II, 198, 1879] from Kimberley.

By Knop [*Oberrh. Geol. Verhandl.* 1889, 10; 1890, 20] from Jagersfontein, in the Orange Free State, about 60 miles S.E. from Kimberley.

No optical examination was made in any of these cases, and it is therefore difficult to say if any of the minerals described are identical with the present.

Some material at the British Museum, supposed to be the mineral described in Maskelyne and Flight's paper, consists of green fragments of the size of small peas, apparently very similar to the present mineral. Their paper, however, speaks of "green grains not larger than a canary seed." The analysis by Flight agrees in the main with mine, but shows the presence of a little lime and a trace of nickel, which I have failed to detect, and does not include any manganese, which is a marked, though not very plentiful, constituent of the present mineral.

A specimen in the British Museum, labelled "Diopside from Colesberg Kopje," is probably identical with the blackish green stone mentioned as being found with the rhombic pyroxene described in the present paper.

It seems, therefore, probable that the material comes from the mines in the Kimberley district, and is associated with red garnet and blackish green diopside in the blue ground.

A similar mineral appears to be found elsewhere in association with diamond-bearing materials, as the British Museum possesses a very similar specimen among a set of minerals from Jagersfontein.

The group of rhombic pyroxenes has been variously subdivided by different observers. Excluding the altered products, bastite, diaklasite, &c., which have a different optical orientation, the unaltered minerals have been differently grouped under the names enstatite, bronzite, and hypersthene, according to the percentage of FeO. Kenngott suggested that minerals having the + acute bisectrix perpendicular to (001) (up to 10 per cent. FeO) should be classed as enstatite, and those with more FeO, having the − acute bisectrix perpendicular to (100), as hypersthene. Tschermak applied the name enstatite arbitrarily to minerals with less than 5 per cent. FeO, bronzite to those having 5-15 per cent., and hypersthene to those richer than this. Des Cloizeaux used a similar arbitrary classification with < 6, 6-10, > 10 per cent of FeO to define the three species. Hintze proposes to restrict the term bronzite to varieties showing metallic lustre, due to "schillerization," and a parting parallel to $b(010)$, and to include varieties poor in FeO under enstatite, those rich in

FeO under hypersthene. The obvious boundary is at about 10 per cent. FeO, corresponding to the change in optical sign.

According to this arrangement the present mineral, with 5·0 per cent. FeO, will be classed as enstatite.

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2. *On a Method of illustrating the Variation of Thermal Conductivity of Crystals in different directions.*

[Read Feb. 1, 1898.]

WHILE endeavouring some time ago to produce, for demonstration purposes, a satisfactory specimen to show the "Curve of Conductivity for Heat," I hit upon a method which may be worthy of mention, as it is exceedingly simple, and gives results which are at once clearly visible and permanent.

I have as yet only tried the method on gypsum and copper sulphate, but it might, no doubt, be applied to other substances containing water of crystallisation.

The gypsum crystals on which the experiments were made were obtained from Shotover Hill, near Oxford.

A stout brass wire ($\frac{3}{16}$ inch. dia.) is filed at one end to a conical point. It is then supported in a vertical position with its point resting on the face of the crystal, and is heated by means of a Bunsen burner directed horizontally at a point 1 or 2 ins. above the end. The water of crystallisation is driven off by the heat, and an opaque white spot formed round the point. This spot has an elliptic outline, which approximates to the curve of conductivity.

If figures be produced on faces belonging to different forms, they can be seen to vary, in the directions and ratios of their axes, in accordance with the symmetry of the crystal (Fig. 1). Figures may readily be obtained with a major axis of 5-6 mm. or more, but beyond this size the outline is rather apt to become irregular, the opacity extending outwards in streaks which, on the cleavage face, run nearly parallel with the edge b/l, [010 : 111].

Fig. 1.

No advantage appears to be gained by screening the crystal from the direct radiation from the source of heat.

Under the microscope the white patch is seen, near the margin, to consist of dots, which (with a $\frac{1}{4}$ in. objective)

show a form like that of the "Verwitterungsflecken" figured by Sohncke (*Zeits. Kryst.* XXX, 1, 1899).[1]

The outline of the figures is usually somewhat indefinite, as the dots, which overlap in the centre, are at the edge more sparsely distributed. The shading-off is, however, fairly regular, and allows of the determination of the ratio $\left(\frac{a}{b}\right)$ of the axes of the ellipse, with some approach to accuracy. I have measured some of the smaller figures on a cleavage face under the microscope, with the following results:—

Face.	Outline.	a	b	$\frac{a}{b}$	mean $\frac{a}{b}$
(010) Cleavage	very sharp	10·0	9·2	1·09	1·129
	sharp ...	13·5	12·0	1·116	
	,, ...	13·0	11·6	1·12	
	fair ...	14·0	12·0	1·166	
	hazy ...	14·0	12·5	1·12	
	,, ...	13·0	11·5	1·13	
	very sharp	12·5	11·2	1·12	
	fair ...	15·6	13·2	1·18	
	,, ...	14·0	12·5	1·12	

Using the same method of heating, combined with Senarmont's wax coating, I obtained from 8 ellipses a mean ratio, $\frac{a}{b}=1{\cdot}151$, the limits being 1·077 and 1·25. A nearer approximation between the two methods is hardly to be expected, on account of the disorganisation of the structure of the crystal by the high temperature. The value obtained by Senarmont on gypsum from Montmartre was $\frac{a}{b}=1{\cdot}23$. The opacity extends downwards from the surface into the crystal, inside which it has an ellipsoidal shape, which, in the case of faces inclined to the plane of symmetry, is seen to be oblique to the surface.

The sharpness of the figures is improved if the irregularities of the face have been first removed by grinding with water on a sheet of ground glass.

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[1] By exposing crystals of Gypsum from Bex to a temperature of about 100° in an air bath, Pape (*Pogg. Ann.* cxxxv. 4, 1868) obtained elliptical figures pointing to the existence of an ellipsoid ("Verwitterungsellipsoïd"), similar to those calculated by him in the case of copper sulphate, &c. Later observers, *e.g.* Sohncke (*l.c.*), have produced by the same method polygonal and not elliptical spots.

The figures on the face *b* are usually traversed by 3 radiating cracks, somewhat resembling the percussion figure of mica. The principal of these runs parallel to the edge *b*/*l*, [010 : 111] ; another parallel to the edge *b*/*m*, [010 : 110]; and the third makes an angle of about 16° with the direction of fibrous fracture, lying between this and the vertical axis.

Some cleavage plates of gypsum from Montmartre, which I have tried, do not give quite such regular figures as the Shotover material, but the radiating cracks and the Sohncke figures are particularly clear.

The production of the larger figures may occupy an hour, but good small figures may be made in a few minutes.

Senarmont's first paper (*Ann. Chim. Phys.* [3], XXI, 466, 1847) on the conductivity of crystals for heat, mentions that he obtained similar dehydration figures in gypsum when the wire passing through the perforated crystal was strongly heated. It would seem, however, either that the observation has escaped notice (with the exception of an incidental mention by Jannettaz (*Ann. Chim. Phys.* [4], XXIX, 23, 1873), or that the simplicity of the method, especially in the form described above, and its adaptation to demonstration purposes, have not been recognised.

According to the few experiments I have made, copper sulphate does not readily yield such good figures as gypsum, but the deviation from a circular form is, nevertheless, quite apparent.

NOTE.—*A Modification of Senarmont's Process.*

In the case of stibnite, I have found that a thin layer of ammonium chloride, obtained by sublimation, answers well as a substitute for Senarmont's wax coating. The application of a heated point in the same manner as with gypsum, volatilises the salt, and leaves the surface of the crystal (cleavage plate) exposed. The resulting figures are clearly visible, but the specimens must of course be subsequently protected from injury in a glass tube or otherwise.

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3. *A twin crystal of Sapphire.*

[Read June 20th, 1899.]

AMONG the specimens which have been recently added to the Oxford collection is a twin crystal of sapphire, of which it may be worth while to give a description in view of the rarity of well-formed twins of this mineral.

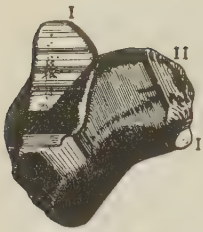

Fig. 1.

The crystal is shown about the natural size in the accompanying figure (Fig. 1); its weight is 10·23 grams. The two individuals are of somewhat unequal size, the largest (II) being 1 in. long by about ½ in. thick, the smaller (I) flattened and rather thinner. The edges are rounded and dull, as if worn by water, but portions of the faces still retain their original brilliant lustre.

The faces lie in the zones $[a, c] = [1\bar{1}0, 111]$, and are much striated. The front zone of (I) yields a series of angles which are arranged symmetrically on the two sides of a face $a(1\bar{1}0)$, (not present), and hence appear to correspond to definite faces—

$$\epsilon\{12.1.\bar{10}\}, \quad \mu\{10.1.\bar{8}\}, \quad \xi\{17.2.\bar{13}\}$$
$$\pi\{45.6.\bar{33}\}, \quad \sigma\{29.5.\bar{19}\}, \quad \tau\{14.3.\bar{8}\}$$

The indices are high, as is often the case with corundum, and the forms are all new. The angles are as follows, the mean of the readings for the best pair of faces (ξ) being taken to fix the position of (a)—

		Edges.	Limits.	Observed.	Calculated.[1]
$c : \epsilon$	$111 : 12.1.\bar{10}$	2	84°14′ – 84°21′	84°17½′	84°17′
$c : \mu$	$111 : 10.1.\bar{8}$	2	83 7 – 83 8	83 7½	83 1½
$c : \xi$	$111 : 17.2.\bar{13}$	1	—	81 48	81 39
$c : \pi$	$111 : 45.6.\bar{33}$	1	—	80 19	80 23
$c : \sigma$	$111 : 29.5.\bar{19}$	1	—	77 3	77 5
$c : \tau$	$111 : 14.3.\bar{8}$	1	—	73 17	73 17

At the back of (II) some small bright reentrant cleavage planes are visible, which may perhaps correspond to $n\{31\bar{1}\}$, and $\nu\{13.1.\bar{11}\}$, though no such cleavage or parting seems to have been recorded. The angles are :—

	Observed.	Calculated.
$c : n$ ...	61°17′ ...	61°11′
$c : \nu$ ...	84 48 ...	84 45½

The colour is pale blue, and traces of milky "ghosts," which are yellowish by transmitted light, are visible inside the crystals. There is a brilliant cleavage or parting, parallel to $r\{100\}$, and also a less perfect one, with silky lustre, parallel to the basal plane. A measure-

[1] Axial angle, $\alpha = 85°47'$, $(a : c = 1 : 1{\cdot}363)$.

ment on the goniometer of the angle between the r-cleavage of one individual and the basal cleavage of the other gave the values:—

$100 : \underline{\bar{1}\bar{1}\bar{1}} = \left\{\begin{matrix}56°43'\\57°16'\\58°\ 5'\end{matrix}\right\}$, 3 (good) images being given by the basal plane.

The crystal is therefore twinned about the face (100), the calculated value of the above angle being 57°34′. This is the same twin law which governs the ordinary twin-lamellation of corundum. A small portion of a third individual (III) projects from the main crystal (II), and is proved by the rhombohedral cleavage to be parallel in position to (I).

The density is 3·989. A few small pieces of a greenish-black mineral are embedded in the crystal.

Etched pits, having the asymmetric form shown in Fig. 2, are present on some of the faces, and correspond—so far as can be judged from the upper half of the crystal, on which alone the pits occur—with the assumption of the rhombohedral symmetry of the calcite class.

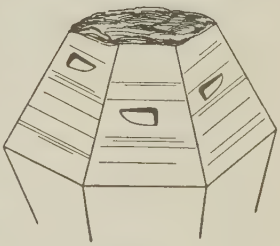

Fig. 2.

The locality of the specimen is uncertain, as it comes from an old collection, but it may probably be from Kashmir.

Twin crystals of sapphire have been previously described in a few cases:—

Jeremejeff, *Verh. k. russ. min. Ges.* (2), XIII, 426, 1877 [Abstr. *Zs. K.* II, 504].

Jeremejeff, *Verh. k. russ. min. Ges.* (2), XIV, 227, 1878 [Abstr. *Zs. K.* III, 438].

Jeremejeff, *Gornyi Journal*, III, 263, 1887 [Abstr. *Zs. K.* XV, 537].

Hidden and Washington, *Am. J. Sc.* (3), XXXIII, 507, 1887 [Abstr. *Zs. K.* XIV, 302].

Barvíř, *Ann. d. k.k. Hofmuseums*, Wien, VII, 135, 1892 [Abstr. *Zs. K.* XXV, 431].

The last observer describes and figures two crystals, of which one somewhat resembles the present specimen. The locality is given as "probably Ceylon."

I have also examined two specimens, kindly lent me by Mr. Francis Powell, which show a second small crystal projecting from the side of the main individual, and find that they are twins obeying the same law. In one of them a third small individual is twinned on the main crystal,

forming a triplet. It seems probable that many of the crystals of sapphire which have small knobs projecting from their surface may really be twins of this nature.

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4. *On Monazite and associated minerals from Tintagel, Cornwall.*

[Read June 19th, 1900.]

IN the *Mineralogical Magazine*, Vol. VI, p. 164 (1885), Prof. Miers described a specimen in the British Museum, which carried crystals of monazite, dispersed on albite and quartz upon a silky slate, and in the absence of any label suggested that it probably came from Cornwall. Shortly after this he visited Tintagel, and in one of the large slate quarries there succeeded in finding a single crystal of monazite, very similar in appearance and association to those on the original specimen described by him.

In the Christmas Vacation of 1899, a small collecting party from Oxford visited the quarry at Tintagel, under the guidance of Prof. Miers, and our search was rewarded with four crystals of monazite and some good specimens of the associated minerals.

Of the numerous quarries in the neighbourhood in which albite and quartz are to be found, only one appears to yield monazite, namely, the large (though now but little worked) quarry about $1\frac{1}{2}$ mile southwards along the coast from Tintagel Castle, which is marked on the 6 in. Ordnance map as "Lanterdan Quarry," but is locally known as part of "West Quarry."

The rock is a Devonian slate, which, just at this point, possesses a peculiar silky lustre. It is traversed by numerous straight joints running roughly in a N.E. and S.W. direction, which dip at a steep angle, and are lined with crystals of albite and quartz, and (in some places) calcite.

The monazite usually lies upon the albite in the joints, but one of the crystals found lies in a small secondary crack directly on the slate.

This Cornish occurrence of monazite offers no exception to the generalisation that this mineral is always accompanied by some form of TiO_2, for rutile is found along with it on the albite, and anatase occurs in the neighbouring "Lambshouse Quarry," a few hundred yards to the north.

Monazite.

Most of the crystals are of the common habit, forming rather thick tables parallel to $a(100)$, and of a reddish-brown colour. The finest of those we obtained is about $2\frac{1}{2}$ mm. long (b-axis), and shows the forms :—

$a\{100\}$; $w\{101\}$; $e\{011\}$; $i\{\bar{2}11\}$; $z\{\bar{3}11\}$; $r\{111\}$; $m\{110\}$; $q\{701\}$.

It is a twin upon the face $a(100)$, and appears to be more or less interpenetrant. The specimen on which it occurs consists of albite, with quartz and calcite and rutile needles. The form $q\{701\}$ was originally discovered by Miers on the specimen in the British Museum, and as it does not seem to have been again observed, its occurrence on the present crystal confirms his suggestion with regard to the locality of that specimen.

The crystal mentioned above as lying directly on the slate, differs from the others both in its colour (a darker brown) and its habit, which is quite exceptional. It is tabular parallel to $b(010)$, and lies on a face of this form. I have measured the angles of the exposed portion without detaching the crystal from the matrix, and find the following forms:—

$b\{010\}$; $u\{021\}$; $e\{011\}$; $v\{\bar{1}11\}$; $o\{\bar{1}21\}$; $m\{110\}$; $n\{120\}$; $\mu\{130\}$; $w\{101\}$; $r\{111\}$; $\eta\{\bar{1}32\}$; $\theta\{\bar{1}22\}$.

Of these, μ, η, θ are new, and are established by the following angles:—

			Edges.	Limits.	Observed.	Calculated.[1]
In the zone $[bnm]$	$b\,\mu$	010:130	2	19°56′—20°26′	20°11′	19°29½′
	$n\,\mu$	120:130	1	..	9° 0′	8°28½′
,, $[uv]$	$u\,\eta$	$02\bar{1}:13\bar{2}$	1	..	[17°][2]	16°34′
	$v\,\eta$	$11\bar{1}:13\bar{2}$	1	..	[22°15′][2]	22°56′
,, ,, $[ev]$	$e\,\theta$	$011:\bar{1}22$	1	..	20°58′	20°26½′
	$v\,\theta$	$\bar{1}11:\bar{1}22$	1	..	18°29′	18° 9½′
	$u\,\theta$	$021:\bar{1}22$	1	..	25°33′	25°16′

The new faces are all distinct, though small, and μ is particularly bright. This crystal is shown in the accompanying figure (Fig. 1).

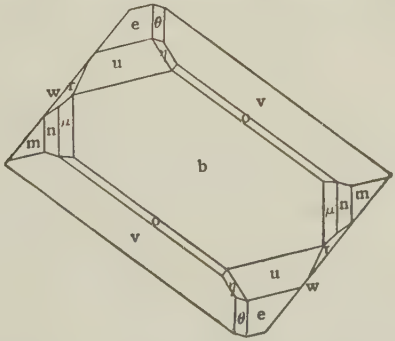

Fig. 1. Monazite.

[1] $a:b:c=0{\cdot}9693:1:0{\cdot}9256$ $\beta=76°20'$ (E. S. Dana.)

[2] Angles obtained by method of maximum illumination

Rutile.

The rutile found associated with the monazite is peculiar, as it forms very fine hair-like needles of a golden colour, lying quite loose upon the albite, and often matted together. Similar needles are also occasionally found enclosed in the quartz crystals.

Thin layers of rutile, of the same colour, and showing the "sagenite" structure, are also found in cracks in massive quartz in the same quarry along with chlorite.

Albite.

The albite occurs in good crystals, sometimes attaining a length (parallel to $x(\bar{1}01)$) of 2 cm., and often covers considerable areas of the faces of the joints. It is usually white, though sometimes stained with ochre, and the smaller crystals are often perfectly transparent.

The following forms are present:—

$b\{010\}$; $m\{110\}$; $M\{1\bar{1}0\}$; $z\{1\bar{3}0\}$; $c\{001\}$; $n\{0\bar{2}1\}$; $o\{\bar{1}\,\bar{1}1\}$; $\delta\{\bar{1}\,\bar{1}2\}$; $p\{\bar{1}11\}$; $x\{\bar{1}01\}$; $y\{\bar{2}01\}$.

Besides these, a small striated face (ξ) occurs on some crystals on the edge c/δ, making an angle of 3°—4° with the face c. The measurements are too uncertain to admit of the definite assignment of indices, but the form is not far from $\{\bar{1}.\bar{1}.16\}$, for which $c\xi = 3°22'$.

In sodium light, the extinction angles are—

On $c\{001\}$, somewhat variable, but usually about $+3°$ to 4°.

On $b\{010\}$, $+20°$.

These values would correspond to a nearly pure soda-felspar, as would also the emergence of a bisectrix through b, at a slight inclination to the normal.

Quartz.

The perfectly clear crystals of quartz, which mostly have a diameter of about 1 cm., but are also found considerably larger, occur with albite and calcite in nests along the joints. They are interesting on account of their commonly rhombohedral termination (the faces of $\{r\}$ being usually much larger than those of $\{z\}$), and from the frequency of twins.

Faces of $s\{4\bar{1}\bar{2}\}$ are very common, but $x\{4\bar{1}\bar{2}\}$ appears to be absent.

Twins according to two laws occur, viz.:—

(1) Rotation twins—twin axis $\perp c\{111\}$—(the common form).

(2) Reflection twins—of the kind described by Prof. Lewis as "laevo dextro-gyral, β"—which may be explained in a simple manner as inter-

penetration twins, of which the two individuals are related to one another by reflection over the equatorial plane.

Only two examples of the second law were obtained. They are represented in Fig. 2, and are characterised by the right- and left handed striation on the two halves of an *s*-face.

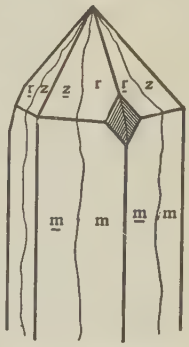

Fig. 2. Quartz twin.

Some of the crystals of quartz contain fine golden needles of rutile.

Pyrite.

On some of the specimens minute brown grains are to be seen on and among the needles of rutile, on which they are often strung like beads. These appear under the microscope to be very perfect model-like crystals of pyrite, showing a combination of a pyritohedron with the octahedron and narrow faces of the cube.

Striated cubic crystals of pyrite of larger size also occur embedded in the slate.

Calcite.

The calcite is always dull on the surface, and forms crystals from 1 to 4 cm. in diameter, the smaller being sharp, but the larger very coarse and rough. Owing to the dullness of the faces, it was necessary to cement small fragments of microscope cover-glass to them in order to obtain measurements. The latter are only approximate, owing to the difficulty of getting the covers to lie flat on the smaller faces. Hence it is impossible to be certain of the indices, which in calcite are often not simple, and in assigning probable indices I have assumed that the faces belong to the nearest form given in Irby's tables.

The smaller crystals are usually surrounded by an equatorial belt of flat plates resembling "schiefer spar," of very peculiar appearance, in parallel position. The basal planes of the schiefer spar, though much pitted and lying at different levels, are very brilliant, and yield a single perfect image of the goniometer signal.

Three habits may be distinguished :—

(1) Large, coarse, rounded crystals, apparently combinations of scalenohedra and rhombohedra.

(2) Rather flat scalenohedra (up to 2 cm. dia., but usually smaller), the points of which project from a bed of the schiefer spar, and are sometimes truncated by a small bright face of $c\{111\}$. The scalenohedron approximates to $\{310\}=\{21\bar{3}4\}$.

(3) Small scalenohedra, either near $v\{20\bar{1}\} = \{21\bar{3}1\}$, or differing somewhat from it—perhaps $\{46.\bar{5}.\bar{3}2\} = \{17.9.\bar{2}6.3\}$—, combined with an inverse rhombohedron, near $\varepsilon\{22\bar{1}\} = \{01\bar{1}1\}$, and small faces of a very flat scalenohedron, perhaps $\{10.4.1\} = \{21\bar{3}5\}$, and possibly also $\{310\} = \{21\bar{3}4\}$.

Crystals of types (2) and (3) are very symmetrically developed. Some of those of (2) are twinned about $e\{011\} = \{\bar{1}012\}$, as is shown by the mutual inclination of the basal planes of the schiefer spar.

The calcite appears to be always associated with the quartz crystals and collected in definite nests, with or without albite, which latter is more abundant than either of the other two minerals. Rutile in fine needles occurs in these nests as well as on the albite alone.

Anatase (from Lambshouse Quarry).

This mineral occurs with small opaque white albite crystals, in small steel-blue octahedra (not exceeding 1 mm.), bounded by $p\{111\}$ and $k\{112\}$, striated and alternating with each other, with minute planes of $o\{107\}$ and $e\{101\}$.

This may probably be the locality mentioned by Greg and Lettsom for anatase, under the name "Tintagel Cliffs," though we did not find any of the "adularia" said by them to be associated with it.

Conchite, a new Form of Calcium Carbonate.[1]

By Agnes Kelly.

(Communicated by Prof. H. A. Miers.)

[Read June 19th, 1900.]

IN the course of an investigation on calcareous secretions in the animal kingdom, and more particularly on molluscan shells, I found that the latter did not consist of aragonite, as G. Rose[2] and Sorby[3] had supposed, but of a negative, uniaxial mineral, which is distinguished by most of its properties from calcite, and for which I propose the name conchite (κόγχη, shell). I further found that conchite occurred naturally in many localities—always as a crystal aggregate. Its properties were investigated on such, as well as on the conchite in shells.

Chemical Composition.—Several shells consisting of conchite were analysed, both qualitatively and quantitatively. In Cardium edule, besides $CaCO_3$ and possible traces of NaCl, I found no inorganic constituent. The following percentages of CO_2 and CaO were determined :—

$CO_2 = 42{\cdot}45$ per cent.
$CaO = 54{\cdot}63$,,

97·08 per cent.

The remaining 2·92 per cent. was organic matter, which could not be determined directly. In Cyrena (sp ?) only CaO was determined, the calculated $CaCO_3$ was 97·2 per cent.

No quantitative analyses were made of naturally occurring conchite, but the various incrustations consisted mainly of $CaCO_3$; those formed under observation in kettles and water baths contained also traces of iron.

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[1] A communication on conchite was laid before the Bavarian Academy on 5th May, 1900, and afterwards published in the *Sitzungsberichte der math.-phys. Classe* of that Academy.

[2] G. Rose, *Vorkommen des Aragonits und Kalkspaths in der organischen Natur*; *Abh. k. Akad. d. Wiss in Berlin*, 1858.

[3] Sorby, Presidential Address, *Quarterly Journal of the Geological Society*, 1879.

Solubility.—Conchite dissolves readily in acids, but it has not yet been shown by direct experiment whether it is more soluble than calcite or not. That it is certainly very much less stable than calcite under the action of atmospheric agencies is seen by comparing the behaviour of conchite and calcite-shells found as fossils. Sorby showed that in all older formations those shells only which he considered to be calcite were preserved as such, the others were either disintegrated or present as casts alone. I have been able to confirm most of Sorby's statements as to the presence of calcite; his aragonite shells are generally conchite, for no aragonite whatsoever is to be found in the animal kingdom. Cornish and Kendall[1] published a long list of the fossils found as shells or as casts in the Coralline Crag, stating that the shells were calcite, the casts aragonite. In this case also I have been able, for many of the genera mentioned, to demonstrate the calcite character of the one series, and the conchite character of the other series, by direct observation. In only one case, that of Serpula, does a fossil occur well preserved, which I have proved to consist of conchite.

The instability of conchite is further shown by Klement's[2] experiments on the artificial preparation of dolomite. Finely-powdered $CaCO_3$, together with crystalline magnesium sulphate and a saturated solution of NaCl, was heated in a closed retort to a constant temperature for a definite number of hours. The solution was then filtered and washed, and the percentage of $MgCO_3$ determined. Calcite heated for 10 hours to 100° gave traces only of $MgCO_3$; aragonite heated for 48 hours to 91° gave 34·6 per cent.; for 68 hours to 90°, 38 per cent. $MgCO_3$. Corals from a group in which I have been able to find conchite secretions only, gave:—Madrepora prolifera heated for 48 hours to 90° 38·5 per cent., Madrepora humilis 41·4 per cent. and Stylopora (sp?) 41·9 per cent. $MgCO_3$. Klement concluded that these corals consisted of aragonite, since conchite was unknown to him, but the increase in the amount of $MgCO_3$ formed in the experiment with the corals over that in the experiments with aragonite, indicate, quite apart from direct observation, that there is a still more unstable form of $CaCO_3$, this being conchite. Since all the important reef-building corals have skeletons of conchite, its instability and the possibility of its transformation into dolomite are of importance for the theory of the origin of dolomite.

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[1] *Geological Magazine*, 1888, p. 66. "On the Mineralogical Constitution of Calcareous Organisms."

[2] Ueber die Bildung des Dolomit. *Tscherm. Min. Petr. Mitt.* 1895, XIV, 526.

Crystallisation from aqueous solution.—The conditions under which conchite crystallises out of water have not been determined with any exactitude. It was noticed, however, that in an a paratus used for obtaining distilled water, the spiral which was immersed in the ordinary hard tap water of Munich was thickly coated with $CaCO_3$ at the top, where it was hot, less thickly in the middle turns, where it was hardly warm to the touch, and was quite bare at the bottom, where the temperature was that of the water. The incrustations from the top and middle of the spiral consisted entirely of conchite, only the very lowest deposits contained some calcite as well.

On leaving solutions of calcium bicarbonate to evaporate at ordinary temperatures, calcite only was obtained, but at temperatures from 30° to 100° C. conchite in increasing proportions was also deposited. G. Rose, in his experiments on the artificial formation of aragonite, considered that the prisms formed under those conditions were aragonite. A careful examination of their properties, and especially the measurement of the index of refraction for the ordinary ray, shows them to be conchite. The prisms obtained on mixing boiling solutions of $CaCl_2$ and Na_2CO_3 or $NaHCO_3$ can similarly be shown to be conchite. I was able to examine only one deposit formed at a temperature markedly above 100° C., viz. an incrustation formed in a boiler under 7·5 atmospheres at 168° C., and it consisted entirely of aragonite, as proved by the biaxial interference figure.

We know little of the conditions of crystallisation of the calcareous secretions in the animal kingdom, but the following two points are noticeable :—

(1) The conditions under which calcite or conchite crystallises out seem to differ very slightly, for we get the outer layer of Pinna and Mytilus formed of calcite, the inner of conchite. Also in animals which secrete various calcareous structures we may get both varieties represented in the same animal, for example, Helix shell and Spiculum Amoris consist of conchite, its epiphragm and egg-shell of calcite ; and Teredo has valves consisting of conchite and a tube of calcite.

(2) We cannot trace the influence of temperature as in deposition from bicarbonate solutions. In the secretions of cold-blooded animals, *i.e.* at ordinary air or water temperatures, we get on the whole more conchite than calcite. The only shells formed at comparatively high temperatures are bird's egg shells (about 37°C), and they are without exception calcite.

Though, like Vater,[1] I have so far been unable to obtain anything but calcite deposits from inorganic solutions at ordinary temperatures, the existence of conchite molluscan shells points to the possibility, under suitable conditions, of the deposition of conchite also at such temperatures.

Behaviour on heating.—Conchite resembles aragonite and ktypeite in being converted into calcite by heating, but differs from aragonite in undergoing the change at a considerably lower temperature.

This can be most readily demonstrated by parallel experiments; for example, in mercury vapour (360° C.) or in melting lead (325°) conchite is converted into calcite, but aragonite undergoes no change. Aragonite crystals break up between 373° and 380°, but only after heating to 405° was I able to see a uniaxial interference figure, and thus demonstrate the change.

Conchite begins to undergo the alteration between 300° and 310°, as can be proved by the occurrence of the twinned planes and cleavage characteristic of calcite. During the change the position of the principal axis is unaltered.

In aragonite and conchite we have two unstable forms of $CaCO_3$, as proved by the change which they undergo on heating, and in the case of aragonite by the greater solubility, as determined by Dr. H. W. Foote.[2] We have had indications that the solubility of conchite is also great, but exact measurements have yet to be made. The fact that up to 100° we get conchite as well as calcite crystallising out of solution, and at 168° aragonite only, is another instance of Ostwald's general statement in his *Grundriss der allgemeinen Chemie*, that on a change of condition and passage into a more stable one, not the variety of the substance which is most stable under the new conditions will tend to be formed, but that which is the least stable.

Specific Gravity.—Since only crystal aggregates were at my disposal there was always a tendency for the specific gravity to come out too low on account of porousness. The highest value obtained by a direct measurement was = 2·865 for an incrustation from a kettle. Crystal aggregates from Karlsbad and other incrustations from kettles and water baths were between 2·830 and 2·845. For Cyrena, from determinations of the specific gravity, the percentage of $CaCO_3$, and the specific gravity of organic matter, the value 2·874 was calculated.

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[1] Ueber den Einfluss der Lösungsgenossen auf die Krystallisation des Calcium carbonats, *Theil II*, *Zeitsch. f. Kryst.* 1894, XXII, 209; *Theil IV*, 1895, XXIV, 378.

[2] *Zeitsch. f. Phys. Chemie*, 15th June, 1900. "Uber die physikalisch-chemischen Beziehungen zwischen Aragonit und Calcit."

The hardness is considerably greater than that of calcite.
No *cleavage* was observed.

Optical Properties.—Conchite is uniaxial and negative like calcite. It is true that, more particularly in true nacreous layers, which invariably consist of conchite, a biaxial interference figure with a small optical angle is sometimes seen, although in general we have accurately uniaxial interference figures. Since nacreous layers consist of numbers of thin parallel lamellæ two possibilities are open—(1) that the mineral forming the nacreous layer is biaxial, and as in the case of uniaxial mica the uniaxial character is due to superposed lamellæ of equal thickness with all the principal axes parallel, but the secondary axes of successive lamellæ at right angles to one another; (2) that the mineral is uniaxial, and that the biaxial character is due to want of exact parallelism of the optical axes of the lamellæ. The reasons for thinking the second alternative the more probable are—

(1) The comparative rareness of the biaxial interference figure, and the want of constancy of the optical angle. In quite a small section of the shell of Cyclas cornea, for example, the angle varied considerably, and on examining a number of shells some were found to give accurately uniaxial interference figures.

(2) In sections through prismatic structures, such as the outer layer of Pandorina inæquivalvis, or the inner of Lithodomus dactylus or Chama macrophylla, and most inorganic incrustations, where there is no possibility of there being superposed lamellæ, the interference figure is always uniaxial.

The *indices of refraction* were determined for sodium light.

(*a*) By the *method of total reflection*. Since only crystal aggregates with the axes of the crystals more or less parallel, and no single crystals, were at my disposal, it was impossible to obtain very exact readings. Many observations were made by means of a prism (Wollaston method). The means for polished slabs of the following shells were: —Strombus gigas, $\epsilon = 1{\cdot}527$, $\omega = 1{\cdot}661$; Cyrena, $\epsilon = 1{\cdot}527$, $\omega = 1{\cdot}662$; Trigonia Lamarkii, $\epsilon = 1{\cdot}524$; Pinna squamosa (nacreous), $\epsilon = 1{\cdot}524$; Turbo sp.?; $\epsilon = 1{\cdot}527$.

Mr. W. J. Pope was kind enough to determine for me the values of ϵ for two shells by means of the Abbé Pulfrich Total-refractometer, and found for Strombus gigas $\epsilon = 1{\cdot}523$ and for Cyrena $\epsilon = 1{\cdot}526$.

Dr. Melczer also made some very careful readings for me by means of a similar instrument. A highly polished slab of Strombus gigas

was found to behave as a biaxial mineral with a small optical angle, the indices being $\alpha = 1{\cdot}523$, $\beta = 1{\cdot}659$, $\gamma = 1{\cdot}662$.

(*b*) *Microscopic Method.*—Prismatic crystals were examined under the microscope with one nicol. When parallel to the one arm of the cross wires, ε would have its minimum value; when parallel to the other arm, ω would be obtained. Two Thoulet's solutions were prepared, the first of such a concentration that its refractive index for sodium light was the same as ε, so that in sodium light, on focussing up or down, the crystal did not appear either lighter or darker than the solution; the second was similarly adjusted to equal ω. The refractive indices of the solutions were measured either directly on an Abbé's refractometer, or the specific gravity was measured and the refractive index calculated from Goldschmidt's tables. Both methods were found to agree to a unit in the third decimal place, so the latter as the simpler was usually resorted to.

The mean values obtained were $\varepsilon = 1{\cdot}524$ and $\omega = 1{\cdot}661$.

Probably we may take these values as being correct to $\pm$ 1 in the 3rd decimal place, since they agree with the best values obtained by the method of total reflection.

The *birefringence* of conchite is accordingly considerably lower than that of calcite, about 0·137. This was also proved directly by observing sections of conchite and calcite of the same thickness in polarised light; for in sections parallel to the optic axis conchite shows colours of a lower order than calcite, and in sections perpendicular to the optic axis conchite shows fewer rings in its interference figure.

The *forms* in which conchite crystals may occur are as follows:—

(1) Prisms and acicular crystals. As such it is deposited from aqueous solutions on evaporation. The various naturally-occurring crystal aggregates all consist of prisms, and some shells, *e.g.* Pandorina inæquivalvis, consist in part of conchite prisms.

(2) Plates parallel to the base. This is the form in which the conchite of nacreous layers occurs.

(3) Rhombohedron-like crystals, with the long axis of the rhombohedron inclined at about 45° to the optical axis. They occur in Strombus and most other gastropods.

Occurrence of Conchite. Animal Kingdom.—A series of about 150 specimens, chosen from all the lime-secreting groups of the animal kingdom, was examined. That no aragonite is present is proved by the constant occurrence of uniaxial interference figures, by the value of ω not exceeding 1·661 (for aragonite $\beta_D = 1{\cdot}6816$, $\gamma_D = 1{\cdot}6859$), and by

the change to calcite at about 300°. The following tests were applied to distinguish between calcite and conchite.

(1) Specific gravity—calcite, 2·715; conchite, 2·87.

(2) Presence or absence of the twinning planes characteristic of calcite.

(3) Minimum value of ϵ—for calcite $\epsilon_D = 1{\cdot}486$; conchite $\epsilon_D = 1{\cdot}524$.

(4) Presence or absence of a change on heating.

As thus determined, the occurrence of conchite or calcite in the animal kingdom is as follows:—

Foraminifera, calcite.

Calcareous sponges, calcite.

Hydrocorallinæ, conchite.

Alcyonaria, calcite, except Heliopora, which is conchite.

Madreporaria, conchite.

Echinodermata, calcite.

Polyzoa, calcite.

Brachiopoda, calcite.

Mollusca. Lamellibranchiata.—Anomia, Ostrea, Pecten and the outermost layers of Pinna and Mytilus, calcite; all the rest conchite.

Gastropoda.—All conchite except Patella and Ianthine.

Opercula of Turbo and Nerita, conchite.

Cephalopoda and Scaphopoda, conchite.

Chætopoda.—Tube of Serpula, conchite.

Crustacea, calcite.

Egg shells of Bulimus, Helix, Alligator, and all birds, calcite; of Tortoise, conchite.

Otoliths of Gadus and Frog, conchite; of Sturgeon, calcite.

The same tests were applied to distinguish conchite in *inorganic nature*. It was found to occur in the following localities:—

Karlsbad, as the spheres in a pisolitic deposit. The spheres are considerably larger than those found to consist of ktypeite. Also as various varieties of Sprudelstein.

Schemnitz in Hungary, blue and brown incrustations.

Alt-sohl in Hungary, a brown incrustation.

Ringenwechsel near Schwatz in Tyrol, a blue incrustation.

Yellowstone Park, Sinter.

Various specimens of Flos Ferri were all found to be conchite, and the fur in kettles was generally conchite, sometimes with an admixture of calcite.

Amorphous Calcium Carbonate.

F. Linck showed that when $CaCO_3$ is precipitated it often appears first in the form of little spheres, which do not depolarise, and only later

become crystalline. If a calcium salt and a carbonate be allowed to diffuse into one another across a very viscid gum solution, such globules, together with crystals, may be obtained as a permanent preparation. As will be seen from their behaviour on heating, these globules constitute the most unstable of all the forms of $CaCO_3$, so that their appearance forms another case in illustration of Ostwald's generalisation, and one would indeed expect them to be precipitated first of all whenever the conditions were favourable. Whether they can crystallise afterwards as conchite, aragonite, or ktypeite or only as calcite is not known; the other unstable forms of $CaCO_3$ can all be converted by heat into calcite, but, so far as is known, never into each other. If the conversion of the globules into calcite is alone possible, their appearance would always condition the formation of calcite, and conchite, for example, could only be deposited when no globules had appeared.

I found in the course of these investigations that the calcium carbonate in the two posterior æsophageal glands of the earth-worm consists of just such globules in the amorphous condition. Moistened with water they very quickly become crystalline, but if they are dried at 100° and the last traces of water removed by treatment with absolute alcohol, they remain permanently amorphous.

Lowering the temperature has no action upon the globules; no change was called forth by leaving for several hours at the temperature of boiling water, but raising the temperature to only 160° to 170°C is enough to cause them to become crystalline.

An exact determination of the specific gravity was not possible, but by means of determinations of the specific gravity of the dried glands, of the organic substance, and of the percentage of $CaCO_3$, the specific gravity can be calculated to have the value 2·1. Similar determinations on the carapaces of Astacus and Julus gave values of 2·2, but these are still more inexact, for as well as about 50 per cent. $CaCO_3$, there is about 6 per cent. $Ca_3(PO_4)_2$ present.

The index of refraction was measured by the microscopic method, and found to be 1·538. Even under the highest magnification, and with the most sensitive methods, no action on polarised light could be observed.

Amorphous calcium carbonate occurs frequently in the animal kingdom, for example, as globules in the mucus of Helix, and not as globules in the carapaces of Astacus, Squilla, Julus and in the egg shell of the grass snake. On maceration with water or on heating it becomes crystalline, which explains why it is not found to occur as a mineral.

The alteration of Pyrite by underground water.

By John W. Evans, LL.B., D.Sc.,
Formerly State Geologist in Mysore.

[Read June 19th, 1900.]

IT has for many years been proposed to form a reservoir with an area of some 36 square kilometres for irrigation purposes near Hiriyur in Northern Mysore, by erecting a dam at Marikanave, where the River Vedavati or Hagari crosses a rocky ridge running north-north-west and south-south-east.

Doubts were raised as to whether the rock would form a sufficiently firm foundation, but Mr. Robert Bruce Foote, late Superintendent of the Geological Survey of India, and my predecessor as State Geologist in Mysore, reported that it was in every way suitable for the purpose. The engineers, however, were apprehensive that the water from the tank would penetrate into the rock below the dam, and disintegrate it in the same manner as the rock of the ridge, which has suffered considerable decomposition from the continued action of surface water during long periods of time. A committee was accordingly formed consisting of two engineers and two geologists, Mr. T. H. Holland, of the Geological Survey of India, and myself, to report on the subject.

An excavation had been made on the northern bank of the river, where it passes through the ridge. The unaltered rock was found at a depth of four or five metres below the level of the river in ordinary flood. The strata exposed appear to belong to the Dharwar formation, the earliest of the non-fossiliferous systems of southern India that shows evidence of a sedimentary origin. The beds at Marikanave consist of ferruginous schistose slates and chlorite schists striking parallel with the direction of the ridge. The cleavage and stratification, which are indistinguishable, are nearly vertical. The slate is the predominant rock, but chloritic bands are repeatedly interstratified with it. Both, but more especially the slate, contain a large amount of iron pyrite. Not only are laminæ of pyrite intercalated parallel to the stratification, but the joint planes are occupied by films of the same material. This is also widely disseminated through the substance of the rock, which was, however, found, when tested in its

unaltered condition, to possess more than the strength required by the engineers.

But in the ridge, and wherever the surface water had penetrated, the pyrite has been oxidised and removed. That in the joint planes was apparently first attacked, most of the iron was dissolved out, and only a little powdery ferric hydrate remained, which was soon washed away, and the rock became a mass of loose tile-like fragments. These, too, suffered decomposition, partly by the removal of the contained pyritic material, and partly as a result of the action of the sulphuric acid produced by the decomposition of the pyrite, sulphates of the bases in the rock being formed[1] and removed in solution, leaving only a certain amount of incoherent earthy material. The question for decision was whether underground water derived from the tank would ultimately have the same effect on the rocks below the dam.

Pyrite is of very frequent occurrence in the older rocks of the south of India. In many cases where they have been exposed to the action of surface weathering it has disappeared, the empty cavities which it once filled being the only indication of its former presence. Elsewhere, though the rock is quite unaltered in general character and apparently as strong as ever, the pyrite has been replaced by exact pseudomorphs in limonite, with or without cores of the original material.

It is at once obvious that the retention of the iron and the unaltered character of the rock must be due to the presence in the water, that effected the oxidation of the pyrite, of some substance that reacts with the sulphate of iron and sulphuric acid formed, so as to precipitate the iron and prevent the acid from corroding other parts of the rock. The only compounds likely to be present in any quantity that can produce this result are the carbonates of the alkaline earths and alkalis. As a general rule carbonate of lime must be the principal agent in the reaction.[2]

The changes that occur may be expressed by the equation :—

$$4FeS_2+15O_2+3H_2O+8CaCO_3=(Fe_2O_3)_2(H_2O)_3+8CaSO_4+8CO_2.$$

A simple calculation will show that the occurrence of complete pseudomorphs of limonite after pyrite implies the retention of the whole of the iron. The density of pyrite varies from 5·2 to 4·83. Four

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[1] $FeS_2+H_2O+4O_2=FeSO_4+H_2SO_4$. A slight incrustation of hydrous aluminium sulphate was detected at one point by Mr. Holland. It is probable that sulphurous acid is at first formed, but is at once oxidised to sulphuric acid.

[2] The action of carbonates in promoting the formation of limonite from pyrite has been recognised by Dr. Justus Roth, *Allgemeine und Chemische Geologie*, I, pp. 101-5, 236.

gramme molecules (each of 119·24 grammes) of pyrite will therefore occupy a space of $\frac{477}{5{\cdot}2}$ to $\frac{477}{4{\cdot}83}$ —that is 92 to 99 cubic centimetres. Limonite has a density of from 4 to 3·6, so that one gramme molecule of the complex limonite combination, containing the same amount of iron as the four gramme molecules of pyrite, will occupy a space of 93 to 103 cubic centimetres, which is practically identical with the volume of the pyrite.[1]

If all the iron is to be retained in the pseudomorph, it is obviously necessary that the carbonates required to react with the iron and hydrogen sulphates formed by the oxidation of the pyrite should be present in the same water that provides the oxygen. The amount of oxygen soluble in water at 15° C. is about 30 litres per cubic metre. At normal pressure this will amount to 1·27 gramme molecules or 40·4 grammes of oxygen in a cubic metre, and will be enough to fully oxidise both the iron and the sulphur, as in the above equation, of ·339 gramme molecules of pyrite, and it will require twice that number of gramme molecules of carbonates (considered as normal carbonates and excluding carbonic anhydride in a free state or combined only with water), that is 40·4 grammes of the CO_3 group to react with the sulphates resulting from such oxidation.

The highest amount of oxygen in ordinary spring or river water among the analyses given in the 1877 edition of Watts's *Dictionary of Chemistry* under the article "Water" is only 11 litres per cubic metre.[2] The average is 7 litres.

The following table gives the details of the oxidising power of these quantities of dissolved oxygen and the carbonates required to react with the oxidised products[3]:—

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[1] If the iron had been converted into hæmatite the volume would have been 60 to 65 cc.; if into magnetite 61 cc.; if into turgite 75 to 78; if into göthite 80 to 88; while if it had passed into xanthosiderite it would have exceeded in volume the limonite. Accordingly, if all the iron be retained and none added, limonite is the only oxide or hydrate of iron that can form exact pseudomorphs after pyrite. It seems possible that the amount of space available may sometimes determine the quantity of water which enters into combination with the ferric oxide.

[2] Among mineral waters one analysis gives 13 litres. The highest in Thorpe's *Dictionary of Applied Chemistry* is 7·26 litres (III, p. 964).

[3] The identity of the figures in the 4th and 7th columns is of course accidental.

	Oxygen in cubic metre.			Pyrite oxidised.	Sulphates formed and carbonates required.	CO_3 (as normal carbonate) required.
	litres.	gramme molecules.	grammes.	gramme molecules.	gramme molecules.	grammes.
Maximum oxygen soluble at 15° C. and 760 mm.	30	1·27	40·4	·34	·68	40·4
Maximum oxygen recorded in ordinary spring or river water	11	·47	14·8	·12	·25	14·8
Average oxygen in river and spring water	7	·30	9·4	·08	·16	9·4

Among the 89 analyses of spring and river water (excluding mineral waters) given in the same edition of Watts's *Dictionary of Chemistry*, 76 have more than 9·4 grammes of the CO_3 group (combined as above) per cubic metre, 74 more than 14·8 grammes, and 68 more than 40·4 grammes; the average being 127 grammes. There is therefore in most cases far more than the amount of carbonates required.

The percentage of oxygen in the water of the proposed reservoir would probably be rather less than the above average, both on account of the higher temperature and because of the lower pressure at a height of about 700 metres above sea level. The presence of limestone in the drainage area and the occurrence of calcareous concretions in the recent alluvium of the river leave no doubt that the reservoir would contain an ample amount of carbonates to ensure that any pyrite it might oxidise in its incipient penetration of the rock would be at once converted into compact limonite completely filling the same space, thereby preventing to a great extent the further extension of the action of the water and preserving the strength of the rock. It would at the same time neutralise any sulphuric acid formed which would otherwise have attacked and dissolved the bases present.

As a general rule none of the calcium sulphate formed will be deposited; for the amount resulting from the reaction above described would be insufficient to saturate the water even though it had been saturated with oxygen which was all employed in oxidising pyrite, and the whole of the carbonate reacting with the sulphate formed were calcium carbonate. In that case the calcium sulphate produced would amount to ·68 gramme molecules, or 92 grammes in a cubic metre of water—which is capable of dissolving as much as 2,591 grammes at 18°C. Gypsum is, however, occasionally found in pseudomorphs after

pyrite with or without a kernel of limonite. This is probably attributable to the slow evaporation of the water *in situ*.[1]

I have made a few simple experiments on the subject of this paper. I placed 1·060 grammes of powdered pyrite in a low beaker within a larger vessel containing distilled water which was frequently changed, mainly by means of a syphon which allowed the water to fall into the vessel, drop by drop, at intervals of a few seconds. After about four months of this treatment the pyrite was still bright, there being scarcely a trace of iron oxide present. There was however a loss of weight of ·0136 grammes—representing pyrite which had passed into solution as ferrous sulphate and sulphuric acid, the former being no doubt afterwards converted into ferric sulphate.

At the same time a practically identical amount (1·062 grammes) of similar powdered pyrite was placed in a beaker of the same shape, in a vessel containing New River water, which was renewed in the same manner as the distilled water. The former was, on titration, found to contain 161 grammes per cubic metre of the CO_3 group (combined with alkalis or alkaline earths, and estimated as normal carbonate). After the same period of treatment a considerable amount of hydrated ferric oxide, resembling limonite in appearance, was visible amongst the pyrite and on the sides of the beaker. As the liquid remaining was allowed to evaporate a little gypsum was also seen, but was easily dissolved out with distilled water. The total loss in weight, after the removal of the gypsum, was only ·0033 grammes, which represented the difference in weight between the pyrite decomposed and the ferric hydrate formed. If the whole of the iron in the pyrite which was decomposed were converted into a ferric hydrate having the composition of limonite, the loss in weight would theoretically amount to 22 per cent. of the pyrite decomposed. As the water was in both cases added drop by drop, and the vessels in which the experiments were conducted exposed to the air an equal amount of surface, which was large in proportion to the volume of the liquid, it is reasonable to suppose that the actual amount of oxygen present in solution was practically the same in the two experiments (being in excess of that usually found in spring or river water), and we may infer that the amount of pyrite oxidised was the same in each case. On the supposition that this was so, and that in the New River water all the iron of the decomposed pyrite remained as limonite, the theoretical loss in weight that might have been expected would work out as ·0030, which is closer to the figures

[1] Roth, *loc. cit.* p. 236.

actually obtained than would have been expected, taking into account the conditions under which the experiment was performed and the probably indefinite character of the hydrate produced.

In another series of experiments small fragments of marcasite were placed in a vessel of distilled water. At the end of two months they were only slightly tarnished, but had diminished in weight from 7·453 to 7·430 grammes. A slight film of ferric hydrate was visible on the surrounding glass. Similar fragments were placed in another vessel filled with water, in which lumps of calcium carbonate were also placed. In less than twenty-four hours ferric hydrate was visible on the glass in the immediate neighbourhood, and in two months a considerable amount had accumulated both on the fragments and round them. Similar results were obtained with almost equal facility when such fragments were placed in a vessel in which New River water was allowed to fall drop by drop.

Similar experiments were conducted with zinc blende, which received a brown coating in calcareous water, but was unaltered in distilled water. Copper pyrites in calcareous water was coated by a similar brown ferruginous film, which was however slightly iridescent. In distilled water it was unaltered, though traces of iron could be detected in the solution. Further action would no doubt have resulted in the formation of appreciable quantities of copper sulphate. In old copper workings near Shimoga, in the north of Mysore, the action of surface water has resulted in the formation of fine stalactites of copper sulphates.

No effect was observable in the case of galena in the brief space of two months during which the experiments lasted.

Kupfernickel, smaltite and mispickel were unaltered in water containing carbonate of lime.

In distilled water kupfernickel was coated with a green film, indicating the formation of annabergite. In the case of smaltite, a white powder, probably arsenic trioxide, was deposited round the specimen, which showed scarcely any perceptible traces of erythrine being formed. No change was perceptible in the case of mispickel. This was contrary to expectation; the mineral is extensively disseminated through the crystalline schists in Mysore, and under the action of surface water all the sulphur is oxidised, the iron is dissolved out as sulphate, and the sulphuric acid attacks and removes a large proportion of the bases of the rock, the final result being a soft earthy material strongly impregnated with yellowish and greenish arsenates of iron, which sometimes extends over a distance of hundreds of metres.

Conclusions.

Where sulphides are exposed to the action of water free from carbonates, they will usually be slowly removed in solution as sulphates. When sufficient carbonates are present, as is the case with nearly all spring and river water, we may expect metallic carbonates, hydrates and oxides to be formed. In the case of iron it is the hydrate which is normally the first product. Free carbonic anhydride plays apparently no part in the formation of oxides, hydrates and carbonates from sulphides. When carbonates are not present in the water acting on the rock, the sulphides will usually be oxidised and removed as sulphates. The action of distilled water on metallic arsenides results in the formation of arsenates, which are in most cases insoluble. The presence of carbonate of lime seems in this case to retard the action.

A List of New Mineral Names.

By L. J. Spencer, M.A., F.G.S.,

Assistant in the Mineral Department of the British Museum.

SINCE the publication, three years ago, of the first of these lists at the end of Volume XI of the *Mineralogical Magazine*, so many new mineral names have been given that a second list may be useful as a completion to Volume XII. In addition to names which have recently been published are a few earlier names which are not to be found in some of the larger works of reference. The numerous compounded chemical and mineral names for artificial substances prepared by Doelter, Lemberg, Thugutt and others, have, with one or two exceptions, been omitted.

Ægirine-augite. H. Rosenbusch, *Mikrosk. Physiogr.* 3rd Ed. 1892, I, 537; Rosenbusch-Iddings, 4th Ed. 1898, p. 257. Intermediate between augite and ægirite.

Ægirine-diopside. W. C. Brögger, *Skrifter Vid.-Selsk. Christiania*, I, *Math.-natur. Kl.* 1898, No. 6, p. 169. The same as ægirine-augite.

Alite. A. E. Törnebohm [*Ueber die Petrographie des Portland-Cements.* Stockholm, 1897, 34 pp.] *Neues Jahrb. Min.* 1899, I, Ref. 485; *Zeits. Kryst. Min.* 1900, XXXII, 610. Silicate and aluminate of calcium, $x(3CaO.SiO_2)+(9CaO.2Al_2O_3)$. Probably rhombic with hexagonal habit. An important constituent of Portland-cement clinkers; with it are smaller amounts of other crystalline substances of similar composition, namely, *belite*, *felite* and *celite*.

Allingite. A. Tschirch and E. Aweng [*Archiv f. Pharmacie*, 1894, CCXXXII, 660-688] *Journ. Chem. Soc. Abstracts*, 1895, LXVIII (i), 385. A variety of amber (succinite) from Switzerland.

Alumotrichite. (P. Groth, *Min.-Samml. Strassburg*, 1878, p. 257). White, fibrous. Chili. [Probably the same as kalinite].

Alumyte. G. H. Kinahan, *Journ. R. Geol. Soc. Ireland*, 1889, VIII, 66; *Trans. Manchester Geol. Soc.* 1895, XXIII, 165. Alum-clay ("bauxite") of Co. Antrim.

Ancylite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 49. Small yellow crystals of octahedral habit with curved faces. Rhombic.

$4Ce(OH)CO_3\ 3SrCO_3.3H_2O$. South Greenland.

Angolite. E. Breusing, *Neues Jahrb. Min.* 1900, *Beil.-Bd.* XIII, 265. Breithaupt's manganocalcite from Schemnitz was shown by Des Cloizeaux to be a mixture of carbonates with an anorthic hydrated silicate of manganese. To the latter the name *Angolith* is now given, and the composition assigned to it is $H_2Mn_3(SiO_3)_4+H_2O$. It appears to be a zeolite.

Argentopercylite. (*Chem.-Zeit.* 1892, XVI, 1952.) The same as boleite.

Arsenpolybasit. S. L. Penfield, *Zeits. Kryst. Min.* 1896, XXVII, 66. Arsenical polybasite = pearceite.

Arzrunite. A. Dannenberg, *Zeits. Kryst. Min.* 1899, XXXI, 230; Abstr. *Min. Mag.* XII, 308. A bright blue-green crystalline crust. $PbSO_4.PbO+3(CuCl_2.H_2O)+Cu(OH)_2$. Rhombic. Chili.

Baddeckite. G. C. Hoffmann, *Amer. J. Sci.* 1898, VI, 274; *Rept. Geol. Survey, Canada, for 1896*, 1898, IX, R 11. A copper-red, highly ferruginous variety of muscovite occurring as scales in clay near Baddeck, Nova Scotia.

Bardiglione. Comte de Bournon, *Trans. Geol. Soc.* 1811, I, 77. The same as anhydrite.

Barium-parisite. See cordylite.

Barracanite. R. Schneider, *Journ. prakt. Chem.* 1895, LII, 557. Those specimens of cubanite, from Barracanao, Cuba, which give the formula $CuFe_2S_4$, instead of $CuFe_2S_3$ as in the original cubanite. *Cupropyrite* is given as an alternative name.

Barytheulandit. *Neues Jahrb. Min.* 1898, I, Ref. 447. The same as barium heulandite.

Beaconite. M. E. Wadsworth, *Rept. State Board Geol. Survey, Michigan, for 1891-2*, 1893, p. 171. A fibrous variety of talc resembling asbestos, from Beacon, Michigan.

Beckerite. E. Pieszczek [*Archiv f. Pharmacie*, [iii], XIV, 433-6] *Journ. Chem. Soc. Abstracts*, 1881, XL, 687. A brown resin occurring with Prussian amber.

Belite. See under alite.

Bentonite. W. C. Knight, *Engineering and Mining Journ.* New York, 1898, LXVI, 491, 638. An impure clay occurring in the Fort Benton shales, Wyoming. Previously called *taylorite* (see below).

Beresowite. J. Samoiloff, *Bull. Soc. Nat. Moscou*, 1897, p. 290. *Beresovite*, Dana's Appendix, 1899. Indistinct dark red crystals resembling melanochroite. $2PbO.3PbCrO_4.PbCO_3$. Beresovsk, Urals.

Birmite. Dana's Appendix, 1899. The same as burmite.

Bitumenite. T. S. Traill, 1853, *Trans. R. Soc. Edinb.* 1857, XXI, 7. The same as torbanite. Groth (*Tab. Uebers. Min.* 2nd-4th Ed.) gives *bituminite*.

Blätterserpentin. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 135. Lamellar serpentine = antigorite.

Britholite. C. Winther, *Medd. om Grönland*, 1900, XXIV, 190. Rhombic; pseudohexagonal by twinning.

$3[4SiO_2.2(Ce,La,Di,Fe)_2O_3.3(Ca,Mg)O.H_2O.NaF].2[P_2O_5.Ce_2O_3]$.

S. Greenland.

Calcistrontite. Von der Marck, *Verh. Ver. Rheinl.* Bonn, 1882, XXXIX, Corr.-bl. 84. Supposed to be $3CaCO_3.2SrCO_3$, but shown by H. Laspeyres (*Zeits. Kryst. Min.* 1896, XXVII, 41) to be a mechanical mixture of calcite and strontianite. Westphalia.

Carnotite. C. Friedel and E. Cumenge, *Compt. Rend. Acad. Sci. Paris*, 1899, CXXVIII, 532; *Bull. Soc. Chim.* 1899, XXI, 328; *Bull. Soc. franç. Min.* 1899, XXII, pp. 26 and 26 *bis*; *Chem. News*, 1899, LXXX, 16. W. F. Hillebrand and F. L. Ransome, *Amer. J. Sci.* 1900, X, 120. A bright canary-yellow substance impregnating sandstone in Western Colorado. Friedel gives the composition as $2UO_3.V_2O_5.K_2O.3H_2O$, but Hillebrand shows it to be a mixture of minerals.

Catophorite. W. C. Brögger, *Die Eruptivgest. d. Kristianiagebietes, Skrifter Vid.-Selsk.* I, *Math.-natur. Kl.* 1894, No. 4, pp. 27-39, 73; 1898, No. 6, 169 *(Katoforit)*; Abstr. *Min. Mag.* XI, 115. Dana's Appendix, 1899, *Cataphorite*. A soda-iron amphibole between barkevikite and arfvedsonite in its optical characters. Occurs in the grorudite of the Christiania district. A. Osann, *Tsch. Min. Mitth.* 1896, XV, 450; Abstr. *Min. Mag.* XI, 250. Texas.

Cedarite. R. Klebs, *Jahrb. k. Preuss. geol. Landesanst. for 1896*, 1897, XVII (ii), 199. An amber-like resin from Cedar Lake, Canada, previously described under the name chemawinite.

Celite. See under alite.

Cementite. F. Osmond [*Bull. Soc. Encour. Indust. Paris*, 1895, X, 480] *Nature*, 1895, LII, 367; *Zeits. Kryst. Min.* 1896, XXVII, 538. A carbide of iron occurring in steel. Probably Fe_3C, and possibly identical with cohenite (Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 16). To various other microscopic constituents of steel have been given the names, *austenite*, *ferrite*, *martensite*, *perlite (pearlyte)*, *sorbite* and *troostite*.

Chalcolamprite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 160. A member of the pyrochlore group occurring as small regular octahedra with a metallic coppery lustre on the surface. $R''Nb_2O_6F_2+R''SiO_3$; (R=Ca,Zr,Na,Ce, etc.). S. Greenland. Compare endeiolite below.

Chlorarsenian. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 171. The same as chloroarsenian.

Churchillite. A. Dufrénoy, *Min.* 2nd Ed. 1856, III, 280. The same as mendipite. From Churchill, Mendip Hills.

Clinohedrite. (1). A. H. Chester, *Dictionary of the Names of Minerals*, 1896. Breithaupt's Clinoëdrit (=tetrahedrite).

(2). S. L. Penfield and H. W. Foote, *Amer. J. Sci.* 1898, V, 289; *Zeits. Kryst. Min.* 1899, XXX, 587 *(Klinoëdrit)*; Abstr. *Min. Mag.* XII, 133. Monoclinic, domatic class. $Zn(OH)Ca(OH)SiO_3$. Franklin Furnace, New Jersey.

Conchite. Agnes Kelly, *Nature*, 1900, LXII, 239; *Min. Mag.* 1900, XII, 363; *Sitz-Ber. Akad. München*, 1900, 187. A form of calcium carbonate; optically uniaxial and negative, but with higher refractive indices than calcite, and no cleavage or twinning. Occurs as various animal secretions (molluscs, &c.), the fur of kettles, and in the hot springs of Carlsbad, Bohemia.

Cordierite-pinite. H. Gemböck, *Zeits. Kryst. Min.* 1898, XXIX, 305; 1899, XXXI, 248. Pinite when derived from cordierite.

Cordylite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 42. Wax-yellow, club-shaped hexagonal crystals, isomorphous with parisite. $(CeF)_2Ba(CO_3)_2$. Also called *barium-parisite*. S. Greenland.

Courtzilite. (*17th Ann. Rept. U.S. Geol. Survey, 1895-6*, Part III, 752). A kind of asphaltum.

Cubeite. Dana's Appendix, 1899. See Kubeit.

Cubosilicite. L. Bombicci, *Mem. Accad. Sci. Bologna*, 1899 [v], VIII, 67. The smalt-blue cubes from Tresztya, Transylvania, usually supposed to be pseudomorphs of chalcedony after fluor, are considered to be a definite form of pseudo-cubic silica related to melanophlogite and cristobalite. [Compare guanabaquite.]

Cuprobinnite. A. Weisbach, *Char. Min.* 1880, p. 42. The same as binnite (=tennantite).

Cuprogoslarite. A. F. Rogers, *Kansas Univ. Quart.* 1899, VIII, A 105 *(Cupro-Goslarite)*. Cupriferous goslarite.

Cupropyrite. R. Schneider, *Journ. prakt. Chem.* 1895, LII, 557. An alternative name for barracanite (see above).

Cylindrite. A. H. Chester, *Dictionary of the Names of Minerals*, 1896. The same as kylindrite.

Darlingite. (*Trans. R. Soc. Victoria*, 1866, VII, 80; *Proc. R. Soc. Victoria*, 1897, N.S. IX, 86). A kind of lydian stone from Victoria.

Eastonite. (*The Mineral Collector*, New York, 1899, VI, 118.) A silver-white mica similar in composition to a vermiculite. Easton, Pennsylvania.

Elfestorpite. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 172. The same as elfstorpite.

Endeiolite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 166. A member of the pyrochlore group occurring in small regular octahedra. $R''Nb_2O_6(OH)_2.R''SiO_3$; (R″=Ca,Na,Zr,Ce, etc.). S. Greenland. Compare chalcolamprite above.

Epistolite. O. B. Boeggild, *Medd. om Grönland*, 1900, XXIV, 183. Large thin rectangular plates with a perfect cleavage parallel to the large face which is silver-white with a strong pearly lustre. Monoclinic. $19SiO_2.4TiO_2.5Nb_2O_5.(Ca,Mg,Fe,Mn)O.10Na_2O.21H_2O.4NaF$.
South Greenland.

Erionite. A. S. Eakle, *Amer. J. Sci.* 1898, VI, 66; *Zeits. Kryst. Min.* 1898, XXX, 176. A zeolite occurring as fine woolly hairs. Rhombic. Chemical formula the same as that of stilbite, but with more alkalies and less lime. Oregon.

Erlan. A. Breithaupt, *Vollst. Char. Min.-Syst.* 1823, pp. 64, 208. Massive; green; a mixture of silicates. Erla, Saxony.

Euban. A. Breithaupt (P. Groth, *Min.-Samml. Strassburg*, 1878, 258). A variety of quartz from Euba, Saxony.

Euchlorine. Used by A. Scacchi at the Naples Museum for an emerald-green incrustation found in 1869 on Vesuvian lava. The textbooks of F. Pisani (1875, p. 338) and other French authors state that it is a chloride and sulphate of copper. The first complete description

(E. Scacchi, *Rend. Accad. Sci. Napoli*, 1884, XXIII, 159) gives it as rhombic with the composition $(K,Na)_2SO_4.2CuSO_4.CuO$. An analysis by Rammelsberg (*Min.-Chem. Erg.-Heft*, 1886, p. 87) gives the formula $4(K,Na)_2SO_4.6CuSO_4.3Cu(OH)_2$.

Faserserpentin. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 135. The same as chrysotile.

Fedorowite. C. Viola, *Neues Jahrb. Min.* 1899, I. 121. C. Viola and E. H. Kraus, *Zeits. Kryst. Min.* 1900, XXXIII, 36. *Fedorovite*, Dana's Appendix, 1899. A monoclinic pyroxene near diopside in chemical composition, but near ægirite in optical characters. In all kinds of igneous rocks in the province Rome.

Felite. See under alite.

Florencite. E. Hussak and G. T. Prior, *Nature*, 1899, LXI, 119; *Min. Mag.* 1900, XII, 244, 249. Pale yellow rhombohedral crystals.

$AlPO_4.CePO_4.Al_2(OH)_6$. Isomorphous with hamlinite. Brazil.

Fluor-herderite. S. L. Penfield, *Amer. J. Sci.* 1894, XLVII, 330. Herderite containing fluorine with little or no hydroxyl.

$Ca(BeF)PO_4$. See hydro-herderite.

Glaucamphiboles. H. Rosenbusch, *Sitz.-Ber. Akad. Berlin*, 1898, p. 707 *(Glaukamphibole)*. A group-name to include the alkali-amphiboles, glaucophane, gastaldite, and crossite, which are of dynamo-metamorphic origin, as distinct from the arfvedsonite-amphiboles, arfvedsonite, riebeckite and hastingsite, which occur only as original constituents in igneous rocks.

Glaucochroite. S. L. Penfield and C. H. Warren, Dana's Appendix, 1899; *Amer. J. Sci.* 1899, VIII, 343; *Zeits. Kryst. Min.* 1900, XXXII, 231; Abstr. *Min. Mag.* XII, 316. A member of the olivine group occurring as embedded prismatic crystals with a bluish-green colour resembling beryl. Rhombic. $CaMnSiO_4$. Franklin Furnace, New Jersey.

Goldschmidtite. W. H. Hobbs, *Amer. J. Sci.* 1899, VII, 357; *Zeits. Kryst. Min.* 1899, XXXI, 417. A telluride of gold and silver, Au_2AgTe_6, intermediate between calaverite and sylvanite. Monoclinic. Cripple Creek district, Colorado.

Gonsogolite. (P. Groth, *Min.-Samml. Strassburg*, 1878, p. 258. *Gonsogolith.*) Probably the same as pectolite. Predazzo, Tyrol.

Graftonite. S. L. Penfield, *Amer. J. Sci.* 1900, IX, 20; *Zeits. Kryst. Min.* 1900, XXXII, 433. Indistinct monoclinic crystals, consisting of a fine lamellar intergrowth of light coloured graftonite with darker triphylite. $(Fe,Mn,Ca)_3P_2O_8$. Grafton, New Hampshire.

Grünlingite. W. Muthmann and E. Schröder, *Zeits. Kryst. Min.* 1897, XXIX, 144; Abstr. *Min. Mag.* XII, 45. The Cumberland mineral usually referred to tetradymite (or joseite) was found to have the composition Bi_4S_3Te, and therefore to differ from tetradymite. Probably rhombohedral.

Gunnarite. G. Landström, *Geol. För. Förh.* 1887, IX, 368. $3FeS_2.2NiS$. Probably identical with pentlandite (Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 20). Sweden.

Hancockite. S. L. Penfield and C. H. Warren, Dana's Appendix, 1899; *Amer. J. Sci.* 1899, VIII, 339; *Zeits. Kryst. Min.* 1900, XXXII, 228; Abstr. *Min. Mag.* XII, 316. A member of the epidote group occurring as brownish red cellular masses of minute lath-shaped crystals. Monoclinic. $R''_2(R'''.OH)R'''_2(SiO_4)_3$; ($R''' = Al,Fe,Mn$; $R'' = Pb,Ca,Mn$). Franklin Furnace, New Jersey.

Hardystonite. J. E. Wolff, *Proc. Amer. Acad. Arts and Sci.* 1899, XXXIV, 479; *Zeits. Kryst. Min.* 1899, XXXII, 1; 1900, XXXIII, 147; Abstr. *Min. Mag.* XII, 315. White granular masses. Tetragonal. $ZnCa_2Si_2O_7$. Franklin Furnace, New Jersey.

Hyaloallophane. G. D'Achiardi, *Atti Soc. Toscana Sci. Nat.* 1898, *Proc. Verb.* XII, 32 *(Jaloallofane)*. Allophane containing an excess of silica, supposed to be due to the presence of admixed hyalite (=jalite in Italian). Sardinia.

Hydro-fluor-herderite. S. L. Penfield, *Amer. J. Sci.* 1894, XLVII, 330. Herderite containing both fluorine and hydroxyl.
$Ca[Be(OH,F)]PO_4$.

Hydrogoethite. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 48. $3Fe_2O_3.4H_2O$. Represents a stage in the alteration of göthite to limonite, as hydrohæmatite (=turgite) is a stage between hæmatite and göthite.

Hydro-herderite. S. L. Penfield, *Amer. J. Sci.* 1894, XLVII, 330. Herderite containing hydroxyl in place of fluorine.
$Ca[Be(OH)]PO_4$. See fluor-herderite.

Hydrolite. G. Mackenzie (T. Allan, *Min. Nomencl.* 3rd Ed. 1819). The same as siliceous sinter.

Hydrophlogopite. (W. F. Clarke, *Bull. U.S. Geol. Survey*, 1895, No. 125, p. 49; P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 131). Contains less alkalies and more loosely combined water than phlogopite.

Jaloallofane. See hyaloallophane.

Jocketan. A. Breithaupt (A. Frenzel, *Min. Lexicon Sachsen*, 1874, p. 160). Hydrated carbonate of iron occurring as concretions on limonite. Jocketa, Saxony.

Johnstonite. E. J. Chapman, *Min.* 1848, p. 42. The same as vanadanite.

Johnstonotite. W. A. Macleod and O. E. White, *Papers and Proc. R. Soc. Tasmania, for 1898-9*, 1900, p. 74. A variety of garnet. Named after R. M. Johnston.

Kalgoorlite. E. F. Pittman, *Records Geol. Survey, New South Wales*, 1898, V, 203. Massive, iron-black. $HgAu_2Ag_6Te_6$. Kalgoorlie, Western Australia.

Katoforit. See catophorite.

Kieselmagnesite. (P. Groth, *Tab. Uebers. Min.* 3rd Ed. 1889, p. 52). A compact mixture of magnesite and quartz.

Kietyöite. A. E. Nordenskiöld, *Min. Finland*, 1863, p. 154. Apatite from Kietyö, Finland.

Klinoëdrit. See clinohedrite.

Kochenite. A. Pichler, *Jahrb. geol. Reichs. Wien*, 1868, XVIII, 47; V. von Zepharovich, *Min. Lexicon Oesterr.* 1873, II, 170. A fossil amber-like resin from Kochenthal, Tyrol.

Kordylite. See Cordylite.

Kosmochromit. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 132. The same as kosmochlor.

Kryptomerite. (P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 172). A doubtful borate.

Ktypeite. A. Lacroix, *Compt. Rend. Acad. Sci. Paris*, 1898, CXXVI, 602. H. Vater, *Verh. Ges. Deutsch. Naturf. u. Aerzte, 71 Versamml. zu München, 1899*, 1900, II (i), p. 188 (artificial). A form of calcium carbonate. Optically positive and sometimes biaxial; birefringence much less than in calcite and aragonite. Occurs as pisolites at Carlsbad, Bohemia, and in Algeria. (Compare conchite above).

Kubeit. L. Darapsky, *Neues Jahrb. Min.* 1898, I, 163; 1898, II, Ref. 366. A misprint for rubrite.

Lagoriolite. J. Morozewicz, *Tsch. Min. Mitth.* 1898, XVIII, 147 *(Lagoriolith; Natrongranat)*; Abstr. *Min. Mag.* XII, 314. An artificial soda-garnet with the formula $3(Na_2,Ca)O.Al_2O_3.3SiO_2$. Forms a connecting link between the garnet and nosean groups.

Lamprophyllite. W. Ramsay and V. Hackman [*Fennia, Bull. Soc. Géographie de Finlande*, 1894, XI, No. 2, p. 119] *Neues Jahrb. Min.* 1896, I, Ref. 259; Dana's Appendix, 1899. A mineral, related to astrophyllite, occurring in the nepheline-syenite of the Kola peninsula, Russian Lapland.

Lasur-oligoclase. P. von Jereméeff [Jubilee volume of the St. Petersburg Mining Institute, 1873, Part II, p. 167] *Zeits. Kryst. Min.* 1900, XXXII, 493 *(Lasur-Oligoklas)*. Nordenskiöld's "Lasur-Feldspath" from Lake Baikal is shown to have the crystal elements of oligoclase.

Leucophœnicite. S. L. Penfield and C. H. Warren, *Amer. J. Sci.* 1899, VIII, 351; *Zeits. Kryst. Min.* 1900, XXXII, 239 *(Leukophönicit)*; Abstr. *Min. Mag.* XII, 316. Purplish red to raspberry-coloured crystalline masses. A manganese humite with hydroxyl in place of fluorine. $R_5(R.OH)_2(SiO_4)_3$; (R=Mn,Zn,Ca). Probably monoclinic. Franklin Furnace, New Jersey.

Leucosphenite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 137. White prismatic crystals with wedge-shaped terminations. Monoclinic. $BaNa_4(TiO)_2(Si_2O_5)_5$. South Greenland.

Libollite. J. P. Gomes, *Comm. Dir. Trab. Geol. Portugal*, 1898, III, 240, 290. An asphaltum, resembling albertite, from Libollo, Portuguese West Africa.

Loranskite. M. P. Melnikoff [separate publication, St. Petersburg]; P. D. Nikolaéeff, *Verh. k. russ. min. Ges.* 1897 [ii], XXXV, Protocolle, p. 11; K. Flug, *ibid.* p. 30; Abstracts in *Zeits. Kryst. Min.* 1899, XXXI, 505. A massive black mineral containing Ta_2O_5,ZrO_2,Y earths, etc. Finland.

Lorenzenite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 130. Small acicular rhombic crystals with high adamantine lustre; sometimes colourless with black tips. $Na_2O.2(Ti,Zr)O_2.2SiO_2$. South Greenland.

Lutécine. A. Michel-Lévy and Munier-Chalmas, *Bull. Soc. franç. Min.* 1892, XV, 175. The elements which build up the groupings called lutécite.

Manganberzeliite. L. J. Igelström, *Zeits. Kryst. Min.* 1894, XXIII, 593. The same as pyrrhoarsenite.

Manganglauconite. See marsjatskite.

Manjak. (R. P. Rothwell's *Mineral Industry* for 1897, New York, 1898, VI, 54; 1899, VII, 72. *Trans. Fed. Inst. Mining Eng.* 1898, XIV, 539; XVI, 33, 388). A local name for asphaltum from Barbados, West Indies.

Marsjatskite. E. von Fedorow and W. Nikitin, *Ann. Géol. Min. Russie*, 1899, III, 90, 102. Glauconite containing much manganese *(Manganglaukonit)*; it forms the bulk of a Tertiary sandstone in the Marsjat forest, Urals.

Mayberyite. S. F. Peckham, *Journ. Franklin Inst.* 1895, CXL, 382. Named after C. F. Mabery (not Maybery). The names *mayberyite*, *venturaite* and *warrenite* are proposed in connection with a suggested new classification of petroleum, bitumen, etc.

Melite. F. Zambonini, *Zeits. Kryst. Min.* 1899, XXXII, 161. Hydrated silicate of Al,Fe. Massive. Thuringia.

Metaheulandite. F. Rinne, *Neues Jahrb. Min.* 1899, I, 13, 30. Heulandite from which part of the water has been artificially expelled, causing a variation in the optical characters (Abstr. *Min. Mag.* XII, 312).

Miersite. L. J. Spencer, *Nature*, 1898, LVII, 574. A cubic-tetrahedral modification of silver iodide containing some copper iodide; isomorphous with marshite. Broken Hill, New South Wales.

Mitchellite. J. H. Pratt, *Amer. J. Sci.* 1899, VII, 286. A variety of chromite containing much $MgO.Al_2O_3$. North Carolina. The same as magnochromite.

Moldovite. C. Istrati, *Bult. Soc. Sci. Bucarest*, 1897, VI, 91. A variety of ozocerite from Moldova (Moldavia).

Moronite. S. Calderon and M. Paul, *Anal. Soc. Españ. Hist. Nat.* 1886, XV, 477. S. Calderon, *ibid.* 1894, XXIII, 21. A mixed siliceous and calcareous deposit formed of radiolaria, diatoms, foraminifera, &c. Moron, Spain.

Mossite. W. C. Brögger, *Skrifter Vid.-Selsk. Christiania*, I, *Math.-natur. Kl.* 1897, No. 7; Abstr. *Min. Mag.* XII, 130. Black tetragonal crystals twinned so as to simulate simple rhombic crystals of prismatic habit. $FeNb_2O_6.FeTa_2O_6$. Isomorphous with tapiolite. Moss, Norway.

Müllerite. F. Zambonini, *Zeits. Kryst. Min.* 1899, XXXII, 157. Yellowish green, soft and compact. $Fe_2O_3.3SiO_2+2H_2O$. Nontron, France. Differs from chloropal (nontronite) in having $2H_2O$ instead of $5H_2O$.

Muschketowite. E. von Fedorow and W. Nikitin, *Ann. Géol. Min. Russie*, 1899, III, 87, 99. A pseudomorph of magnetite after hæmatite. Urals.

Narsarsukite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 154. Honey-yellow tabular or cube-shaped tetragonal crystals.

$3Na_2O.Fe'''F.2TiO_2.12SiO_2$. Narsarsuk, S. Greenland.

Nasonite. S. L. Penfield and C. H. Warren, Dana's Appendix, 1899; *Amer. J. Sci.* 1899, VIII, 346; *Zeits. Kryst. Min.* 1900, XXXII, 234; Abstr. *Min. Mag.* XII, 316. White, massive. $Pb_4(PbCl)'_2Ca_4(Si_2O_7)_3$. Probably tetragonal and isomorphous with ganomalite. Franklin Furnace, New Jersey.

Natronanorthite. S. J. Thugutt, *Neues Jahrb. Min.* 1895. *Beil.-Bd.* IX, 561. Abstr. *Min. Mag.* XI, 111, *soda-anorthite.* An artificial compound, $Na_2Al_2Si_2O_8$.

Natroncatapleiite. G. Flink, *Geol. För. Förh.* 1893, XV, 206; *Zeits. Kryst. Min.* 1894, XXIII, 359 *(Natronkatapleït).* Catapleiite containing soda in place of lime.

Natrongranat. See lagoriolite.

Natronmelilith. W. C. Brögger, *Eruptivgest. d. Kristianiagebiets, Skrifter Vid.-Selsk. Christiania*, I, *Math.-natur. Kl.* 1898, No. 6, pp. 69, 366. A tetragonal silicate of Al and Na belonging to the melilite or to the scapolite group. Occurs in the rock called farrisite; Christiania district.

Natronmikroklin. W. C. Brögger, *Die Silur. Etag. Kristianiagebiet*, 1882, p. 262; *Skrifter Vid.-Selsk. Christiania*, I, *Math.-natur. Kl.* 1898, No. 6, p. 11. Dana's Appendix, 1899, p. 5, *soda-microcline.* The same as anorthoclase.

Nigrite. C. A. Peterson, *20th Ann. Rept. U.S. Geol. Survey*, 1899, Part VI, p. 257. A kind of asphaltum from Utah.

Osmite. R. Hermann, *Bull. Soc. Nat. Moscou*, 1836, IX, 228. Iridosmine with 40·83 per cent. of osmium.

Pantellarite. (A. Dufrénoy, *Min.* 1859, IV, 59 *(pontellarite)*; A. Des Cloizeaux, *Min.* 1862, I, 323). The felspar of Pantellaria analysed by Abich in 1840; since called anorthoclase.

Paragite. V. von Zepharovich, *Min. Lexicon Oesterr.* 1873, II, 350. The same as Korallenerz (corallinerz, Dana) or hepatic cinnabar, an ore of mercury in Idria.

Paralaurionite. G. F. H. Smith, *Min. Mag.* 1899, XII, 108, 183; *Zeits. Kryst. Min.* 1900, XXXII, 217. Dimorphous with laurionite, PbClOH. Monoclinic. In Roman lead slags from Laurion, Greece. See rafaelite.

Parianite. S. F. Peckham, *Journ. Franklin Inst.* 1895, CXL, 381. Asphaltum from the Pitch Lake of Trinidad.

Parorthoclase. F. Zirkel, *Lehrb. d. Petrogr.* 1893, I, 238 *(Parorthoklas)*. The same as anorthoclase.

Pelionite. W. F. Petterd, *Catalogue of the Minerals of Tasmania, Papers and Proc. R. Soc. Tasmania, for 1893*, 1894, p. 13. Cannel coal from Mount Pelion.

Philipstadite. R. A. Daly, *Proc. Amer. Acad. Arts and Sci.* 1899, XXXIV, 433; *Bull. Soc. franç. Min.* 1899, XXII, 144. A variety of hornblende from Philipstad, Sweden.

Picroilmenite. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 143 *(Pikroilmenit)*. The same as picrotitanite, a variety of ilmenite rich in magnesium.

Pietricikite. C. Istrati, *Bult. Soc. Sci. Bucarest*, 1897, VI, 65, 93. The correct spelling of Dana's zietrisikite. A variety of ozocerite from Mount Pietricica, Moldavia.

Pilite. E. Schulze, *Lithia Hercynica*, Leipzig, 1895, p. 29. The same as tinder-ore (Zundererz). Formula given as $Pb_2Sb_3S_8$, Harz.

Planoferrite. L. Darapsky, *Verh. deutsch. wiss. Ver. Santiago, Chili*, 1897, III, 423; *Bol. Soc. Nac. Mineria, Santiago*, 1898 [iii], X, 106; *Zeits. Kryst. Min.* 1898, XXIX, 213. Probably rhombic (F. Grünling). $Fe_2O_3.SO_3.15H_2O$. Groth (*Tab. Uebers. Min.* 4th Ed. 1898, p. 74) writes the formula as $SO_4Fe_2(OH)_4+13H_2O$. Chili.

Plumbobinnite. A. Weisbach, *Char. Min.* 1880, p. 42. The same as dufrenoysite.

Plusinglanz. A. Breithaupt, *Vollst. Char. Min.-Syst.* 1823, p. 277. Shown by A. Frenzel (*Tsch. Min. Mitth.* 1900, XIX, 244) to be identical with argyrodite.

Prasochrome. X. Landerer, *Neues Jahrb. Min.* 1850, 813, 682. A dark green alteration product coating chromite. Grecian Archipelago.

Přilepite. E. Bořický, Zepharovich's *Min. Lexicon Oesterr.* 1873, II, 246. A resinous substance occurring as reniform crusts on coal shales at Přilep, Bohemia.

Pseudo-chalcedonite. A. Lacroix, *Compt. Rend. Acad. Sci. Paris*, 1900, CXXX, 430. A form of fibrous anhydrous silica; optically biaxial and negative.

Pseudogaylussite. F. J. P. van Calker, *Zeits. Kryst. Min.* 1897, XXVIII, 556. The "barley corn" pseudomorphs of calcite after gaylussite (or celestite?).

Pseudo-ozocerite. Förtsch, *Zeits. f. Naturwiss. Ver. f. Sachsen u. Thüringen*, 1898, LXX, 322. Ozocerite from Central Persia, differing in some respects from Galician ozocerite.

Pseudoparisite. G. Flink, *Medd. om Grönland*, 1898, XIV, pp. 236 and iii; 1900, XXIV, 179. The same as cordylite (see above).

Pungernite. Bulgarine, *Quart. Journ. Geol. Soc.* 1851, VII, 66. Yellowish brown organic matter from the Silurian of Russia.

Pyraphrolith. (P. Groth, *Tab. Uebers. Min.* 3rd Ed. 1889, p. 156). A mixture of felspar and opal.

Rafaelite. A. Arzruni, *Zeits. Kryst. Min.* 1899, XXXI, 243 *(Rafaëlit)*; Abstr. *Min. Mag.* XII, 308. G. F. H. Smith, *Min. Mag.* 1899, XII, 183; *Zeits. Kryst. Min.* 1900, XXXII, 217. Identical with paralaurionite (see above). San Rafael mine, Chili.

Raspite. C. Hlawatsch, *Ann. naturh. Hofmus, Wien*, 1897, XII, 33; *Zeits. Kryst. Min.* 1897, XXIX, 130; 1899, XXXI, 1; *Records Geol. Survey, New South Wales*, 1898, VI, 51; Abstr. *Min. Mag.* XII, 47. Small yellow or brownish crystals with high adamantine lustre. Dimorphous, with stolzite, $PbWO_4$. Monoclinic. Broken Hill, New South Wales.

Rhodolite. W. E. Hidden and J. H. Pratt, *Amer. J. Sci.* 1898, V, 294; VI, 463; *Min. Mag.* 1899, XII, 133, 145. Garnet ("*rose garnet*") of a rose-red or rhododendron-red colour used as a gem-stone. $2Mg_3Al_2(SiO_4)_3+Fe_3Al_2(SiO_4)_3$. North Carolina.

Robellazite. E. Cumenge, *Bull. Soc. franç. Min.* 1900, XXIII, 17. Black concretionary masses occurring with carnotite in Colorado. Contains V,Nb,Ta,W,Al,Fe,Mn.

Rose garnet. See rhodolite.

Rosenite. C. Zincken, *Pogg. Ann.* 1835, XXXV, 357. The same as plagionite.

Rosstrevorite. (Greg and Lettsom, *Min. of Great Brit.* 1858, p. 105.) Fibrous stellated epidote from near Rosstrevor, Co. Down.

Roumanite. C. Istrati [*Bult. Soc. Sci. Fizice*, 1895, IV, 59; *Anal. Acad. Române*, 1895, XVI] *Bult. Soc. Sci. Bucarest*, 1897, VI, 55; 1898, VII, 272. The same as rumänite.

Sauconite. W. T. Roepper, F. A. Genth's *Mineralogy of Pennsylvania*, 1875, p. 120. A zinciferous clay from Saucon Valley, Pennsylvania. (Analysis in Dana's 5th Edit. 1868, p. 409.)

Schizolite. C. Winther, *Medd. om Grönland*, 1900, XXIV, 196. A variety of pectolite, containing much manganese, occurring as pink prismatic crystals. Monoclinic. S. Greenland. Compare manganopectolite.

Senaite. E. Hussak and G. T. Prior, *Min. Mag.* 1898, XII, 30. Black crystals with the same symmetry as ilmenite (rhombohedral with parallel-faced hemihedrism), to which the mineral is related.
$(Fe,Pb)O.2(Ti,Mn)O_2$. Brazil.

Soda-anorthite. See natronanorthite.

Soda-catapleiite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 100. See natroncatapleiite.

Soda-garnet. See lagoriolite.

Soda-microcline. See natronmikroklin.

Spodiophyllite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 85. Rough, ash-grey, hexagonal prisms with the physical characters of chlorite, but containing no water. $(Al,Fe)_2(Mg,Fe,Mn)_3(Na_2,K_2)_2Si_3O_{24}$. South Greenland.

Staalerts. C. A. Münster, *Nyt Mag. f. Naturv.* 1892, XXXII, 269; *Skrifter Vid.-Selsk. Christiania*, I, *Math.-natur. Kl.* 1894, No. 1, p. 54. A massive steel grey ore which may be "arsenical silver" or argentiferous mispickel. Kongsberg, Norway. *Staalerts* (Norwegian) = *Stahlerz* (Germ.) = *Steel-ore* (Engl.).

Stantienite. E. Pieszczek [*Archiv f. Pharmacie*, [iii], XIV, 433-6] *Journ. Chem. Soc. Abstracts*, 1881, XL, 687. A black resin occurring with Prussian amber.

Stelznerite. A. Arzruni, *Zeits. Kryst. Min.* 1899, XXXI, 232; Abstr. *Min. Mag.* XII, 308. Green, transparent, prismatic crystals resembling brochantite in appearance. Rhombic. $CuSO_4.2Cu(OH)_2$. Chili.

Stokesite. A. Hutchinson, *Phil. Mag.* 1899, [v], XLVIII, 480; *Proc. Cambridge Phil. Soc.* 1900, X, 216; *Min. Mag.* 1900, XII, 274. A colourless crystal with the habit of gypsum. Rhombic.

$CaO.SnO_2.3SiO_2.2H_2O$. Cornwall.

Striegovite. P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 135. The same as strigovite.

Sulphoborite. *Journ. Chem. Soc. Abstracts*, 1893, LXIV (i), 325. The same as sulfoborite.

Sulvanite. G. A. Goyder, *Trans. R. Soc. South Australia*, 1900, XXIV, 69; *Journ. Chem. Soc. Trans.* 1900, LXXVII, 1094. Sulphovanadate of copper, $3Cu_2S.V_2S_5$. Massive; bronze-yellow with metallic lustre. S. Australia.

Szaskaite. (T. A. Readwin, *Index to Mineralogy*, 1867.) The same as calamine ($ZnCO_3$). Szaska, Hungary.

Szechenyiite. J. A. Krenner, *Scientific Results of Count Béla Széchenyi's Travels in Eastern Asia*, Budapest, 1897, III, p. 290 (Hungarian); Abstr. in *Zeits. Kryst. Min.* 1899, XXXI, 503. A soda-amphibole resembling diallage in appearance.

$2Na_2O.10MgO.3CaO.Al_2O_3.16SiO_2$. Occurs embedded in jadeite from Burma.

Tainiolite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 115. A mica occurring in the form of strips. Monoclinic.

$(MgOH)_2(K,Na,Li)Si_3O_8 + H_2O$. South Greenland.

Taylorite. W. C. Knight, *Engineering and Mining Journ.* New York, 1897, LXIII, 600. An impure clay from Wyoming. The name afterwards changed to *bentonite* (see above).

Teruelite. A. Maestre, *Anales de Minas, Madrid*, 1845, III, 264; F. Quiroga, *Anal. Soc. Españ. Hist. Nat.* 1873, II, 249; F. Chaves, *Anal. Soc. Españ. Hist. Nat.* 1891, XX, Actas p. 9. Black, acute rhombohedra (with basal planes) of dolomite from Teruel, Aragon.

Thalenite. C. Benedicks, *Geol. För. Förh.* 1898, XX, 308; *Bull. Geol. Inst. Univ. Upsala*, 1899 (for 1898), IV, 1 *(Thalénit)*. Flesh-red; massive and in dull monoclinic crystals. $H_2O.2Y_2O_3.4SiO_2$.
Österby, Sweden.

Thellite. (*Chem. News*, 1870, XXI, 13, *thelline, thellite*). Damour's yttrium silicate from Brazil (Dana's *Min.* 6th Ed. p. 512).

Titanomagnetite. (P. Groth, *Tab. Uebers. Min.* 4th Ed. 1898, p. 79.) Titaniferous magnetite. $[(Fe,Ti)O_2]_2Fe$.

Torrensite. H. Lienau, *Chem.-Zeit.* 1899, XXIII, 418. A compact reddish grey to sepia coloured mineral occurring with rhodonite at Torrens mine, Hautes-Pyrénées. $MnSiO_3.MnCO_3.\frac{1}{2}H_2O$.

Uranelain. R. Hermann, *Bull. Soc. Nat. Moscou*, 1832, V, 45; *Pogg. Ann.* 1833, XXVIII, 566. A transparent, yellow, gummy substance like rancid oil, containing C, H and O. So-called inflammable snow which fell in gov. Moscow in 1832.

Venturaite. See under Mayberyite.

Vestanite. (C. Hintze, *Handb. d. Min.* 1892, II, 832). The same as westanite.

Viellaurite. H. Lienau, *Chem.-Zeit.* 1899, XXIII, 418. A massive, dark grey mineral from near Vielle-Aure, Hautes-Pyrénées.
$5MnCO_3.2Mn_2SiO_4$.

Von Diestite. E. Cumenge, *Bull. Soc. franç. Min.* 1899, XXII, 25. Telluride of silver, bismuth, etc. Colorado.

Walaite. E. Boricky, *Lotos*, 1869, XIX, 19. The same as valaite.

Warrenite. See under Mayberyite.

Wickelkamazite. A. Brezina and E. Cohen, *Die Structur d. Meteoreisen*, Stuttgart, 1886; E. Cohen, *Meteoritenkunde*, 1894, p. 94. The kamacite surrounding accessory constituents in meteoric irons.

Xanthotitane. P. Groth, *Tab. Uebers. Min.* 3rd Ed. 1889, p. 156 *(Xanthotitan)*. The correct form of xanthitane.

Yttrium-apatite. G. Flink, *Medd. om Grönland*, 1900, XXIV, 173. Apatite containing Y_2O_3 (3·36 per cent.), cerium, etc. South Greenland.

Ziegelite. (*Comm. Dir. Trab. Geol. Portugal*, 1898, III, 203.) The same as Ziegelerz = tile-ore (variety of cuprite).

Zinc-schefferite. J. E. Wolff, *Zeits. Kryst. Min.* 1900, XXXIII, 148. Schefferite containing some zinc. Franklin Furnace, New Jersey.

September, 1900.

NOTES AND COMMENTS.

WE regret to record the death, on June 26th, 1900, of Professor G. H. F. Ulrich, a contributor to this Magazine. Georg Heinrich Friedrich Ulrich was born on July 7th, 1830, at Zellerfeld in the Harz, and graduated at the School of Mines, Clausthal. In 1854 he emigrated to Victoria, and in 1858 was appointed Assistant Secretary to the Mining Commission at Melbourne; later he successively filled in the same colony the posts of Field Geologist of the Geological Survey, Curator of the Technological Museum, and Lecturer on Mining and Mineralogy in the University. From 1879 onwards, he was Professor of Mining and Mineralogy in the Otago University at Dunedin, New Zealand. His death was the result of a fall from a cliff while collecting rock specimens in the neighbourhood of Dunedin.

Professor Ulrich was the author of several reports and papers on mining and mineralogy, commencing in his early days with the minerals of the Harz. One of the most useful from a mineralogical point of view is his "Contributions to the Mineralogy of Victoria," published as a separate pamphlet in 1870, which is really a short treatise on the minerals of Victoria. The Victorian minerals maldonite, selwynite and talcosite were discovered and named by him.

We have received from the publisher, Thomas Murby, a new edition of Rutley's *Mineralogy* (the 12th) and of Skertchley's *Geology* (the 10th), two small but well known volumes belonging to Murby's Science and Art Department Series of Text-books. The *Mineralogy* has been increased by an outline of the modern treatment of Crystal Symmetry, and a table of the 32 classes similar to that in Penfield's *Determinative Mineralogy*. To the *Geology* has been added a section embracing the new requirements of the South Kensington Syllabus, viz. Rock-forming Minerals, Crystallography, Volcanic and Plutonic Rocks, and the Microscopical Examination of Rocks.

The following publications have been recently received:—

From the Agent-General for Victoria several of the Monthly Returns of the Gold Fields of Victoria. From the Greater Britain Exhibition at

Earl's Court, 1899, a Catalogue of the very complete exhibits, mainly of metalliferous ores, in the Queensland Court. Also a Guide to Queensland compiled by C. S. Rutlidge (Dean & Son), which gives a very full account of the resources of the Colony. From the Agent-General for Queensland several detailed Maps of Mining Districts prepared by the Government Geologists. From the Michigan College of Mines a Catalogue containing a full account of the courses of instruction provided in that institution. From the Editor the first number of a new weekly paper entitled *British Mining*.

REVIEW.

Notions de Minéralogie. Par A. F. Renard, Professeur à l'Université de l'État à Gand, et F. Stöber, Chargé de Cours à la même Université. Pp. x. and 374, avec 732 figures dans le texte. Gand, Ad. Hoste, 1900.

The present work is intended primarily for the use of students reading Mineralogy at the University of Ghent and in the affiliated engineering and other schools; but the authors have also kept in view the needs of others, such as chemists and geologists who may wish to gain a knowledge of the subject as an aid to their own special studies. It is divided into two sections, dealing respectively with the general and the systematic parts of the subject.

Part I (pp. 1-189) is devoted to the discussion of the geometrical and physical properties of crystals and the general and chemical characters of minerals. Among the points worthy of note in an elementary book are the adoption throughout of Millerian indices, to the exclusion of the symbols of Naumann, and the free use made of the stereographic projection. The main facts and relations of geometrical crystallography are clearly explained, and some examples are given of the method of "working out" a crystal by means of zones. Questions of calculation involving trigonometry are for the most part omitted.

The systems are discussed at some length, and the principal forms of the holosymmetric and of the more important merosymmetric types and their common combinations described and figured. It is perhaps a little unfortunate that the authors, while using planes of symmetry as the basis for the division into systems, make no reference to the other elements of symmetry, and in the subdivision into classes continue to give prominence to holohedral and merohedral characters, in many cases without considering the symmetry of which these are the outcome. A sketch given of the principles of twinning, and mimetic twinning is illustrated a description of phillipsite.

In view of its doubtful existence, the third type of twin-plane might perhaps have been better omitted. It may be noted also that wulfenite is not now grouped with scheelite as "pyramidal hemihedral," having no equatorial plane of symmetry (though the absence of this is not indicated in the figure given).

In the part allotted to physical crystallography, special prominence is given to the determination of optical characters, in view of their importance in petrographic work, and there is a useful paragraph on the interpretation of partially visible axial figures. Some elementary explanation of the formation of interference figures might with advantage have been added.

Four pages are devoted to a discussion of the ellipsoid of elasticity and the wave surface, but it may be open to doubt how far these will be intelligible to a student after the short acquaintance with the subject gained from the preceding pages.

The thermal, electric and magnetic properties of crystals are shortly treated, and there is a paragraph on optical anomalies.

A noticeable feature of the short section on chemical crystallography is the inclusion of a number of microchemical tests, with figures of the crystalline products. The use of etching figures in determining the symmetry of a crystal finds a place in this part, which concludes with an interesting chapter on the modes of formation of minerals in nature and in the laboratory.

The second division of the book (pp. 191-366) contains good descriptions of about 130 of the more important minerals, together with notes in smaller type on some of the rarer species, of which however a rather excessive number is admitted. The classification adopted is that of Groth's *Tabellarische Übersicht*. At the end is added a useful list of the minerals found in Belgium, with their principal occurrences; the materials of this list have not been previously collected together.

The illustrations are numerous, but the lettering of them is not always very legible. Several printer's errors (especially in indices) will be found which have escaped inclusion in the list of errata.

As a whole, the book forms a useful introduction to the subject of which it treats.

H. L. B.

INDEX TO VOL. XII.

(See also "List of New Mineral Names," p. 378.)

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